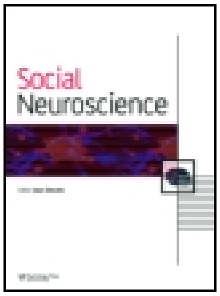

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The Body Action Coding System I: Muscle activations during the perception and expression of emotion

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Body postures provide clear signals about emotional expressions, but so far it is not clear what muscle patterns are associated with specific emotions. This study lays the groundwork for a Body Action Coding System by investigating what combinations of muscles are used for emotional bodily expressions and assessing whether these muscles also automatically respond to the perception of emotional behavior. Surface electromyography of muscles in the arms (biceps and triceps) and shoulders (upper trapezius and deltoids) were measured during both active expression and passive viewing of fearful and angry bodily expressions. The biceps, deltoids, and triceps are recruited strongly for the expression of anger and fear expression predominantly depends on the biceps and the deltoids. During passive viewing, all muscles automatically activate during the passive viewing of anger. During fear perception, a clear activation can be seen in the trapezius, deltoid, and triceps muscles, whereas the biceps shows inhibition. In conclusion, this study provides more insight into the perception and expression of emotions in the body.

Keywords: Surface EMG; Emotion; Body; Muscles; Perception; Expression.

There is a wealth of knowledge about the expression of emotions in the face. For example, it is known which facial muscles, or action units, are used in the expression of facial emotions (Facial Action Coding System; Ekman & Friesen, 1978). Interestingly, muscles used for expressing a certain emotion, such as the zygomaticus major in the cheek for smiling and the corrugator supercilii in the brow for frowning, are also activated by the perception of that emotion, an automatic process that can be measured using electromyography (EMG) (Dimberg & Thunberg, 1998). This process also occurs when stimuli are processed without visual awareness or in response to bodily expressions or vocalizations (Bradley & Lang, 2000; Dimberg, Thunberg, & Elmehed, 2000; Grèzes et al., 2013; Hietanen, Surakka, & Linnankoski, 1998; Kret, Stekelenburg, Roelofs, & De Gelder, 2013; Magnée, Stekelenburg, Kemner, & de Gelder, 2007; Tamietto et al., 2009) and thus probably reflects more than just motor mimicry of the seen behavior. A few studies assessed the overlapping neural mechanisms of perceiving and imitating facial expressions or the correlations between facial muscle activity and BOLD responses. Imitating facial expressions activate the somatosensory and premotor cortices, but this activity also extend to emotion-regions, suggesting that

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imitating an expression does not merely reflect motor behavior (Carr, Iacoboni, Dubeau, Mazziotta, & Lenzi, 2003; Lee, Josephs, Dolan, & Critchley, 2006; Leslie, Johnson-Frey, & Grafton, 2004). More specifically, the neural correlates of automatic facial muscle responses differ per emotion, where reactions of the zygomaticus major have been found to correlate with activity in the inferior frontal gyrus, the supplementary motor area, and the cerebellum, whereas corrugator supercilii activation was correlated with activity of the hippocampus, insula, and superior temporal sulcus (Likowski et al., 2012).;

When it comes to emotional responses in the body, Darwin (1965) already suggested a functional link between emotional reactivity and postural responses as a way to react appropriately to the environment. Whether a similar response as found for muscles in the face may occur for muscles in the body when emotion is observed is not yet known, but it has been found that the body moves away from or freezes upon the perception of aversive and arousing stimuli (Azevedo et al., 2005; Eerland, Guadalupe, Franken, & Zwaan, 2012; Facchinetti, Imbiriba, Azevedo, Vargas, & Volchan, 2006; Hillman, Rosengren, & Smith, 2004; Horslen & Carpenter, 2011; Lelard et al., 2013; Roelofs, Hagenaars, & Stins, 2010; Stins et al., 2011). Also, it is easier to move or push toward appetitive stimuli than to aversive stimuli (Chen & Bargh, 1999; Marsh, Ambady, & Kleck, 2005), which is also done with more muscle force (Coombes, Cauraugh, & Janelle, 2006), although this may only be the case if attention is directed toward the affective content of the target (Rotteveel & Phaf, 2004). In addition, flexing or extending the arm has differential effects on picture ratings (Cacioppo, Priester, & Berntson, 1993) or the startle response (Thibodeau, 2011). Furthermore, studies using transcranial magnetic stimulation (TMS) of the motor cortex showed that action observation is related to motor facilitation of muscles that are used in the execution of the observed movement (Fadiga, Craighero, & Olivier, 2005; Hardwick, McAllister, Holmes, & Edwards, 2012; Romani, Cesari, Urgesi, Facchini, & Aglioti, 2005; Urgesi, Candidi, Fabbro, Romani, & Aglioti, 2006). This facilitation effect is enhanced by emotion (Baumgartner, Willi, & Jancke, 2007; Coelho, Lipp, Marinovic, Wallis, & Riek, 2010; Coombes et al., 2009; Enticott et al., 2012; Hajcak et al., 2007; Oliveri et al., 2003; van Loon, van den Wildenberg, van Stegeren, Ridderinkhof, & Hajcak, 2010). Interestingly, listening to unpleasant sounds or music (Giovannelli et al., 2013; Komeilipoor, Pizzolato, Daffertshofer, & Cesari, 2013), observing negative scenes (Borgomaneri, Gazzola, & Avenanti, 2013), fearful faces (Schutter, Hofman, & Van Honk, 2008), or emotional bodily expressions (Borgomaneri, Gazzola, & Avenanti, 2012) also increase action preparation measured as motor-evoked potentials of muscles in the hands. Finally, there is increasing evidence that affective processing influences activity at the level of the spinal cord. For example, the amplitude of the tendon reflex is increased after watching aversive or sexually arousing stimuli (Bonnet, Bradley, Lang, & Requin, 1995; Both, Van Boxtel, Stekelenburg, Everaerd, & Laan, 2005) and two spinal cord fMRI studies showed that negative emotional stimuli activate those parts of the cervical spinal cord that are related to control of the upper limbs (McIver, Kornelsen, & Smith, 2013; Smith & Kornelsen, 2011).

To sum up, it seems likely that there is a link between observing emotion and responses of muscles in the body, not just in the face. However, to assess whether bodily muscles also respond to the perception of emotions and if so, whether they show the same pattern of activation as during the expression of the emotion, it needs to be explored which muscles are used for which emotional expressions. Thus, the aim of the current study is twofold. The first aim is to lay the groundwork for a Body Action Coding System (BACS), describing which muscles are used in the expression of emotion. To make a beginning with this, we focused on four muscles in the shoulders and arms (the upper trapezius descendens, the anterior deltoid, the biceps brachii, and the long head of the triceps brachii) and assessed their involvement in fearful and angry bodily expressions. These muscles were chosen because their function in moving the shoulders (i.e., shrugging) and arms (i.e., raising the arms and bending them) makes them likely candidates for executing angry and fearful body expressions. Also, these muscles have been found to activate during cognitively stressful tasks (Roman-Liu, Grabarek, Bartuzi, & Choromański, 2013; Willmann & Bolmont, 2012). Therefore, it was hypothesized that these muscles would also activate in response to the perception of emotional bodily expressions.

METHOD

Participants

Forty-four undergraduates of Tilburg University participated in exchange for course credit. Participants read and signed an ethical consent form according to the Declaration of Helsinki and were screened to assess physical, psychological, and neurological health. Nine students were excluded from the analysis; one subject suffered from muscular dystrophy, one had recently suffered a severe concussion, three did not follow instructions, one was an outlier on age (48 years), and three were left-handed. The recording sessions of five other participants were aborted by the researcher, because the participants indicated they felt unwell. The sample therefore consisted of 30 healthy individuals (two males) between 18 and 26 years old (M = 20.1, SD = 2.2) with normal or corrected-to-normal vision.

Stimulus materials and procedure

The experiments consisted of two emotion conditions: fear and anger. Twenty-four videos of 3000 ms were used, in which an actor opens a door followed by a fearful (12 videos) or angry (12 videos) reaction. These stimuli are well recognized and controlled for movement and emotional intensity (Grèzes, Pichon, & de Gelder, 2007; Pichon, de Gelder, & Grèzes, 2008, 2009, 2012). The face of the actor was blurred. The videos were projected life size on the wall with a projector, in front of the participant who was standing upright. In total, there were 72 randomly presented trials: 36 for the anger condition and 36 for the fear condition with an intertrial interval (ITI) between 9 and 11 s, during which a black screen with a white fixation cross on the chest height of the stimulus was shown. The experiment was divided in two blocks of 36 trials with a break in between. This procedure was used in both experiments.

Experiment 1: Passive viewing

The participants were instructed to view all the videos while maintaining an upright posture, the head facing forward, feet positioned 20–30 cm apart, squared but relaxed shoulders, and arms hanging loosely next to the body. The participants were asked to stand as still as possible while keeping a relaxed stance and to minimize unnecessary movements, such as moving the head, shifting stance, or tugging at hair or clothing.

Experiment 2: Imitation

The participants were told that they would see the same videos as in experiment 1 and instructed to mimic the emotional reaction of the actor. Participants were urged to do this as convincingly as possible using their whole body. The subjects first viewed the whole video adopting the same stance as

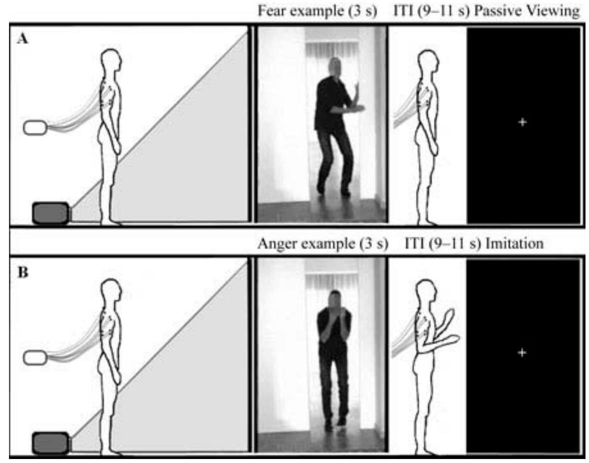

Figure 1. Schematic overview of the experimental setup and trials for experiment 1 (A) and 2 (B).

in experiment 1, and after the offset of each movie imitated the emotional movement of the actor, before returning to their starting position and posture. This was first practiced with the experimenter to assure the subjects understood the procedure. See Figure 1. Experiment 2 always followed after experiment 1. The order of the experiments was not counterbalanced, to prevent habituation to the videos and to keep the participants naïve to the purpose of the study during the passive viewing experiment.

Electrophysiological recording and analyses

The recordings took place in a dimly lit and electrically shielded room. Bipolar EMG recordings were made from the upper trapezius descendens, the anterior deltoid, the biceps brachii, and the long head of the triceps brachii bilaterally. The location of each electrode was carefully established according to the SENIAM recommendations (Hermens & Freriks, 1997) and cleaned with alcohol. Flat-type active electrodes (2 mm diameter), filled with conductive gel, were placed on each muscle with an inter-electrode distance of 20 mm. Two electrodes placed on the C7 vertebrae of the participant served as reference (common mode sense) and ground (driven right leg) electrodes. EMG data were digitized at a rate of 2048 Hz (BioSemi ActiveTwo, Amsterdam, the Netherlands). To reduce subject awareness of the aim of the study, the participants were told that the electrodes measured heart rate and skin conductance. The researcher could see and hear the participant through a camera and an intercom.

The data were processed offline using BrainVision Analyzer 2.0 (Brain Products). Eight channels were created, one for each recorded muscle bilaterally, by subtracting electrode pairs. These channels were filtered using a band-pass filter (20–500 Hz, 48 dB/octave) and a notch filter (50 Hz, 48 dB/octave). The data were then rectified, smoothed with a low-pass filter of 50 Hz (48 dB/octave) and segmented into 9 1-s epochs including a 1-s pre-stimulus baseline. The epochs were visually inspected and outlier trials were manually removed per channel per condition. There exists a large variance in the baseline or "resting" EMG activity across participants but also across muscles. Thus, outliers were not based on a cut-off criterion. Trials with movement or artifacts in the pre-stimulus baseline and trials with overt movement during the projection of the stimulus were rejected and removed. The remaining trials of each channel were averaged, filtered with 9 Hz, down sampled to 20 Hz and exported.

Statistical analyses

Only channels with at least 30 valid trials per emotion condition were kept for analysis. To examine the development of the EMG signal across time, average EMG amplitude of 500 millisecond bins were calculated and divided by the average EMG amplitude of the first second before baseline presentation. This way, EMG magnitude of 16 time points (8 s), of which the first six time points are during stimulus presentation, was expressed as a proportion compared to pre-stimulus baseline, or in other words, change compared to baseline where 1 is no change, a positive number indicates an increase in EMG amplitude, and a negative number indicates a decrease.

The analyses consisted of fitting linear mixed-effects growth models. This technique allows the estimation of individual differences in time course patterns by modeling variances of slopes and intercepts. Also, it is better equipped to handle missing data (such as outliers) or heterogeneous correlations between time points, and it models patterns of activity more flexibly and efficiently than standard ANOVA or repeated-measures ANOVA. In addition, several assumptions for more standard statistic approaches are usually not met by the data, such as homogeneity of regression slopes and case independence, however, this does not pose a problem for multilevel models. To illustrate, the time course of activity of one muscle can be linear, while the other muscle may display a quadratic time course. Also, the outliers per time point per condition can differ. These are problems badly handled by standard ANOVAs, and consequently, multilevel models have been suggested as the standard analysis for psychophysiology studies (Bagiella, Sloan, & Heitjan, 2000). In order to assess whether the EMG signal of a specific muscle changes over time in response to a specific emotion, growth models were fitted to the data after the removal of outliers per time point, starting with a simple model allowing a fixed intercept and a fixed linear effect of time. The model was then extended step by step to include random intercepts, quadratic and cubic effects of time, and random slopes of time. This results in an increasingly complex model with one extra degree of freedom with each step. To assess the model fit, –2 log likelihood was compared and tested with the chi-square distribution. A heterogeneous autoregressive covariance structure (ARH1) was used, which allows for higher correlations between adjacent time points than between time points that are further apart. In this way, the model that best explains the time course of the EMG amplitude of a muscle in response to a specific emotion was determined. Fixed effects represent the overall equation of how EMG activity changes over time, while random effects allow the estimation of an equation for each subject separately. For the passive viewing experiment, all 16 time points were modeled, including the six time points during stimulus presentation. For the imitation condition, only the time period after which the participants started moving was modeled.

RESULTS

The first hypothesis pertains to the question of which muscles we use in the active expression of fearful and angry emotion and thus the results from experiment 2 will be presented first.

Expression of anger

EMG amplitude for angry expressions of the right trapezius muscle showed significant variability across intercepts (Wald $Z = 3.096$, $p = .002$), and a model with a fixed cubic effect of time fits the data well ($F(1, 269.33) = 16.155$, $p < .001$). The EMG time courses of the right deltoid also varied across intercepts (Wald $Z = 2.785$, $p = .005$), and a fixed quadratic effect of time was found ($F(1, 284.70) = 183.681$, $p < .001$). The same was found for the right biceps (Wald $Z = 2.422$, $p = .015$; $F(1, 285.64) = 221.45$, $p < .001$) and the right triceps (Wald $Z = 2.655$, $p =$

TABLE 1

Parameter estimates, 95% confidence intervals, and significance levels of the best fitting model for each muscle on the (A) right and (B) left in the anger imitation condition

			Fixed parameter					Random parameter	
	N		*b*	*SE b*	*95% CI (L)*	*95% CI (U)*		*Variance*	*SE Var*
(A) Parameter estimates of the fixed and random effects in the anger imitation condition of muscles on the right									
Trapezius	28	Intercept	−16.816632	2.653917	−22.041599	−11.591665		0.423723	0.136868
		Linear	4.847297	0.791117	3.289732	6.404862	***		
		Quadratic	−0.379447	0.074934	−0.526978	−0.231917	***		
		Cubic	0.009108	0.002266	0.004646	0.013569	***		
Deltoid	30	Intercept	−36.559576	3.231923	−42.920121	−30.199032		4.535052	1.628668
		Linear	8.187642	0.609520	6.987904	9.387380	***		
		Quadratic	−0.370303	0.027323	−0.424083	−0.316523	***		
Biceps	30	Intercept	−53.078026	4.298910	−61.538455	−44.617597		5.982452	2.470336
		Linear	11.960488	0.815990	10.354370	13.566605	***		
		Quadratic	−0.545642	0.036666	−0.617812	−0.473472	***		
Triceps	30	Intercept	−27.821614	2.394145	−32.532763	−23.110465		2.535705	0.955073
		Linear	6.233984	0.456561	5.335430	7.132539	***		
		Quadratic	−0.278014	0.020593	−0.318543	−0.237485	***		
(B) Parameter estimates of the fixed and random effects in the anger imitation condition of muscles on the left									
Trapezius	28	Intercept	−7.368409	0.884879	−9.110204	−5.626614		0.584604	0.194550
		Linear	1.862532	0.168547	1.530683	2.194381	***		
		Quadratic	−0.084915	0.007625	−0.099927	−0.069902	***		
Deltoid	30	Intercept	−29.107268	2.431887	−33.892811	−24.321724		2.638577	0.941595
		Linear	6.653852	0.462438	5.743717	7.563987	***		
		Quadratic	−0.303527	0.020834	−0.344529	−0.262524	***		
Biceps	30	Intercept	−51.124373	4.181579	−59.353725	−42.895020		4.635856	2.000894
		Linear	11.582544	0.798220	10.011475	13.153614	***		
		Quadratic	−0.528522	0.035980	−0.599338	−0.457706	***		
Triceps	30	Intercept	−26.770849	2.419585	−31.532155	−22.009543		2.302925	0.869177
		Linear	6.044664	0.460794	5.137775	6.951552	***		
		Quadratic	−0.271910	0.020762	−0.312773	−0.231048	***		

Note: ***$p < .001$.

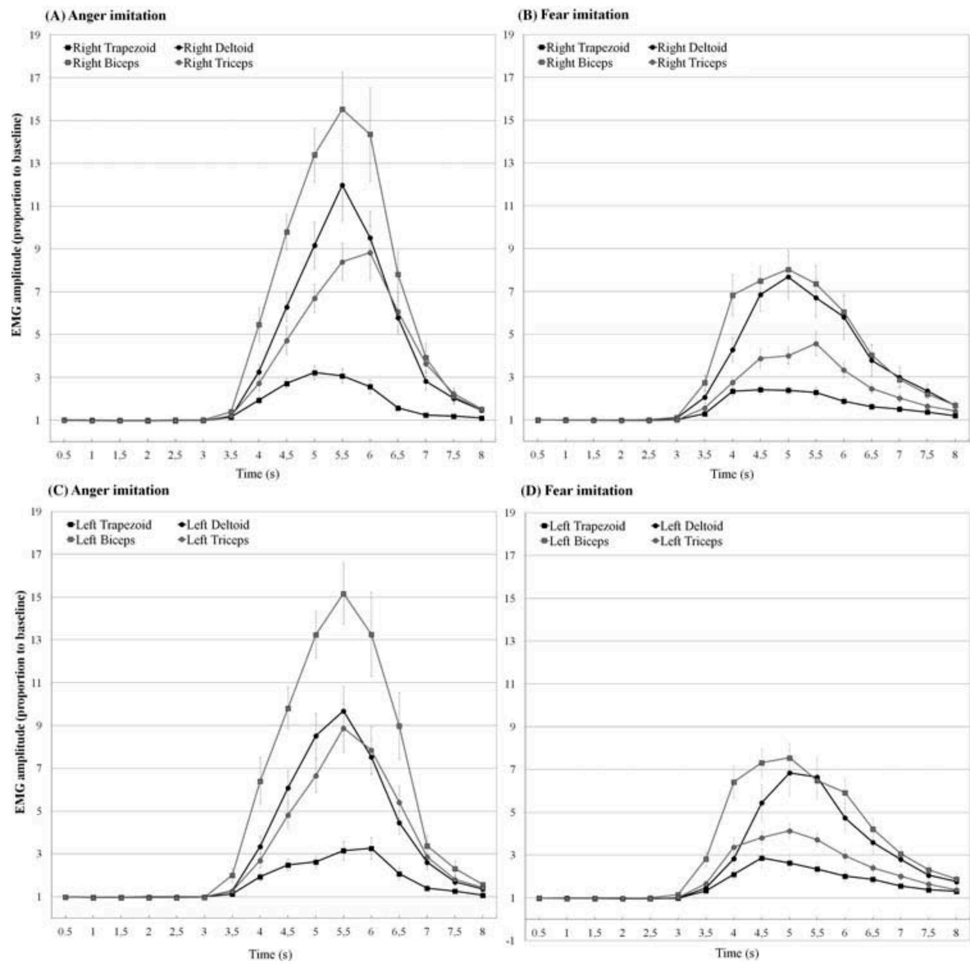

Figure 2. EMG amplitudes and standard errors of the mean during active anger imitation on the right (A) and left (C), fear imitation on the right (B) and left (D). The first 3 s represent EMG activity during stimulus presentation.

.008; $F(1, 293.18) = 182.260$, $p < .001$). See Table 1A and Figure 2A.

Unlike the findings of the right trapezius, a model with random intercepts (Wald $Z = 3.005$, $p = .003$) and a fixed quadratic effect of time ($F(1, 267.40) = 124.023$, $p < .001$) was established in the left trapezius. The same model fits well for the left deltoid (Wald $Z = 2.802$, $p = .005$; $F(1, 291.92) = 212.260$, $p < .001$), the left biceps (Wald $Z = 2.317$, $p = .021$; $F(1, 288.83) = 215.778$, $p < .001$), and the left triceps (Wald $Z = 2.650$, $p = .008$; $F(1, 292.79) = 171.51$, $p < .001$). See Table 1B and Figure 2C.

Expression of fear

The EMG time course of the right trapezius during the active expression of fear was best fitted by a model with random intercepts (Wald $Z = 3.351$, $p = .001$) and a fixed cubic effect of time ($F(1, 266.31) = 37.702$, $p < .001$), and the same was found for the right deltoid (Wald $Z = 3.381$, $p = .001$; $F(1, 288.96) = 15.73$, $p < .001$), the right biceps (Wald $Z = 3.408$, $p = .001$; $F(1, 293.75) = 50.496$, $p < .001$), and the right triceps (Wald $Z = 3.254$, $p = .001$; $F(1, 286.68) = 22.160$, $p < .001$). See Table 2A and Figure 2B.

Also on the left side, the EMG activation of the trapezius during fearful emotional expressions shows significant variation in intercepts (Wald $Z = 3.329$, $p = .001$) and a fixed cubic effect of time ($F(1, 264.58) = 22.721$, $p < .001$). This model also fits the time courses for the left deltoid (Wald $Z = 3.235$, $p = .001$; $F(1, 288.30) = 8.149$, $p = .005$), the left biceps (Wald $Z = 3.230$, $p = .001$; $F(1, 290.38) = 52.256$, $p < .001$), and the left triceps (Wald $Z = 2.710$, $p = .007$; $F(1, 284.636) = 40.598$, $p < .001$). See Table 2B and Figure 2D.

TABLE 2

Parameter estimates, 95% confidence intervals, and significance levels of the best fitting model for each muscle on the (A) right and (B) left in the fear imitation condition

			Fixed parameter					*Random parameter*	
	N		*b*	*SE b*	*95% CI (L)*	*95% CI (U)*		*Variance*	*SE Var*
(A) Parameter estimates of the fixed and random effects in the fear imitation condition of muscles on the right									
Trapezius	28	Intercept	−13.586930	1.774283	−17.080182	−10.0936778		0.363596	0.108490
		Linear	4.195433	0.527254	3.157318	5.2335472	***		
		Quadratic	−0.352304	0.049878	−0.450508	−.2541011	***		
		Cubic	0.009260	0.001508	0.006291	.0122294	***		
Deltoid	30	Intercept	−49.658602	7.469411	−64.359535	−34.9576697		5.257285	1.555001
		Linear	13.789454	2.223715	9.412720	18.1661876	***		
		Quadratic	−1.066311	0.210437	−1.480495	−.6521270	***		
		Cubic	0.025229	0.006361	0.012710	.0377472	***		
Biceps	30	Intercept	−67.983222	7.040261	−81.838563	−54.1278800		4.579910	1.343974
		Linear	19.675100	2.085134	15.571407	23.7787940	***		
		Quadratic	−1.631923	0.196593	−2.018833	−1.2450140	***		
		Cubic	0.042115	0.005927	0.030451	.0537792	***		
Triceps	30	Intercept	−26.628178	3.749136	−34.007319	−19.2490374		1.097177	0.337149
		Linear	7.641949	1.111734	5.453752	9.8301456	***		
		Quadratic	−0.606756	0.104850	−0.813129	−.4003827	***		
		Cubic	0.014878	0.003161	0.008657	.0210983	***		
(B) Parameter estimates of the fixed and random effects in the fear imitation condition of muscles on the left									
Trapezius	28	Intercept	−15.131948	2.489351	−20.0331945	−10.2307014		0.595624	0.178911
		Linear	4.613153	0.738491	3.159094	6.0672112	***		
		Quadratic	−0.384508	0.069690	−0.521726	−.2472903	***		
		Cubic	0.010022	0.002102	0.005882	.0141613	***		
Deltoid	30	Intercept	−38.688450	7.647443	−53.740065	−23.6369339		3.542957	1.095133
		Linear	10.600930	2.260819	6.151131	15.0507285	***		
		Quadratic	−0.799096	0.212823	−1.217980	−.3802126	***		
		Cubic	0.018294	0.006409	0.005681	.0309079	***		
Biceps	30	Intercept	−61.428651	6.126881	−73.487130	−49.3701721		2.388762	0.739662
		Linear	17.776169	1.824166	14.185906	21.3664322	***		
		Quadratic	−1.467461	0.172590	−1.807147	−1.1277750	***		
		Cubic	0.037710	0.005217	0.027443	.0479776	***		
Triceps	30	Intercept	−28.473937	3.266751	−34.903845	−22.0440284		0.436227	0.160963
		Linear	8.332419	0.969981	6.423178	10.2416600	***		
		Quadratic	−0.685778	0.091566	−0.866009	−.5055462	***		
		Cubic	0.017607	0.002763	0.012168	.0230459	***		

Note: ***$p < .001$.

Furthermore, it was hypothesized that the muscles involved in the active expression of emotion also show activation during the passive viewing of these emotions. The results of experiment 1 are shown below.

Passive viewing of angry expressions

The EMG time courses of the right trapezius showed significant variance in intercepts across participants (Wald $Z = 2.778$, $p = .005$), and a model with fixed quadratic effect of time ($F(1, 376.87) = 4.317$, $p = .038$) where the effect of time was allowed to vary across participants (Wald $Z = 2.726$, $p = .006$) fits the data best. The EMG activity of the right deltoids was best explained by a fixed cubic effect of time ($F(1, 434) = 4.651$, $p = .032$) where the intercepts across participants are also allowed to vary (Wald $Z = 3.483$, $p < .001$). For the right biceps, a fixed linear effect of time ($F(1, 420) = 9.691$, $p = .002$) with only varying intercepts was found (Wald $Z = 3.070$, $p = .002$). Last, the EMG amplitudes of the right triceps were found to be cubic ($F(1, 405.05) = 9.164$, $p = .003$) with varying intercepts (Wald $Z = 2.684$, $p = .007$) and time (Wald $Z = 2.654$, $p = .008$). See Table 3A and Figure 3A.

The EMG time course of the left trapezius muscle could be described only by a linear trend in amplitude over time ($F(1, 415.90) = 3.493$, $p = .062$), but the intercepts across participants varied significantly (Wald $Z = 3.585$, $p < .001$). The same model was found to fit the time course of the left deltoid activity (random intercepts; Wald $Z = 3.488$, $p < .001$, linear effect of time; $F(1, 450) = 10{,}632$, $p = .001$) and left biceps activity (Wald $Z = 3.362$, $p < .001$; $F(1, 447.10) = 4.851$, $p = .028$). No significant model was found for the left triceps. See Table 3B and Figure 3C.

Passive viewing of fearful expressions

EMG activity of the right trapezius was best explained by a fixed cubic effect of time ($F(1, 390) = 12.289$, $p = .001$) with varying intercepts (Wald $Z = 3.219$, $p = .001$). EMG activity of the right deltoid changed linearly ($F(1, 445.80) = 18.48$, $p < .001$) over time also with significant variance across intercepts (Wald $Z = 3.397$, $p = .001$). The EMG time course of the right biceps was best explained by a fixed cubic effect of time ($F(1, 406) = 3.866$, $p = .05$) where the intercepts (Wald $Z = 2.617$, $p = .009$) and slopes of the linear effect of time (Wald $Z = 2.047$, $p = .041$) are allowed to vary across participants. The same was found for the right triceps (random intercepts; Wald $Z = 2.279$, $p = .023$, slope; Wald $Z = 2.363$, $p = .018$, fixed cubic effect of time; $F(1, 420) = 5.460$, $p = .02$). See Table 4A and Figure 3B.

On the left side of the body, EMG amplitudes of the trapezius showed a trend for a fixed linear effect of time ($F(1, 416.98) = 3.249$, $p = .07$) with varying intercepts across participants (Wald $Z = 3.448$, $p = .001$). The same model was found to fit the time courses of the left deltoid (Wald $Z = 3.442$, $p = .001$; $F(1, 450) = 17.801$, $p < .001$). No model could be fitted on the EMG amplitudes of the biceps or triceps. See Table 4B and Figure 3D.

DISCUSSION

The first aim of the current study was to start building a BACS and to assess the involvement of four muscles in the execution of fearful and angry body movement. The results show that the four measured muscles in the shoulders and arms are used in both angry and fearful bodily expressions. However, the extent to which the muscles are recruited show a slightly different pattern. Whereas the biceps, deltoids, and triceps are used strongly for the expression of anger, the expression of fear predominantly depends on the biceps and the deltoids. To create a BACS that specifies in a more discriminate manner what combination of action units uniquely describes specific bodily expressions, we need to extend this research in the future to include more muscles and emotions. However, this combination of the recruited muscle patterns together with the intensity of the muscle response already provides a fairly unique description of the two emotional expressions.

Second, we hypothesized that muscles in the body would also respond automatically to the observation of emotional bodily expressions. The results show that it is indeed possible to detect small but significant activations in bodily muscles. The activation patterns found in the passive viewing experiment overlap, but do not exactly match, the found activation patterns in the imitation experiment. The imitation of anger involves all four muscles to some degree, and all four muscles on the right automatically activate significantly during passive viewing of anger. During fear perception, a clear activation can be seen in the trapezius, deltoid, and triceps muscles, whereas the biceps muscle shows deactivation (Figure 3B). The triceps and biceps may thus play an important role when it comes to discriminating between the expression and observation of anger and fear.

Even though the trapezius does not play a major role in the expression of emotion as compared with

TABLE 3

Parameter estimates, 95% confidence intervals, and significance levels of the best fitting model for each muscle on the (A) right and (B) left in the anger passive viewing condition

			Fixed parameter					*Random parameter*	
	N		*b*	*SE b*	*95% CI (L)*	*95% CI (U)*		*Variance*	*SE Var*
(A) Parameter estimates of the fixed and random effects in the anger condition of muscles on the right									
Trapezius	27	Intercept	1.00026	0.004919	0.990394	1.010130		0.000353	0.000127
		Linear	–0.00123	0.000973	–0.003142	0.000685		0.000004	0.000001
		Quadratic	0.00011	0.000052	0.000006	0.000209	*		
Deltoid	29	Intercept	1.00388	0.005832	0.992387	1.015372		0.000285	0.000082
		Linear	–0.00518	0.002429	–0.009955	–0.000406	*		
		Quadratic	0.00077	0.000327	0.000126	0.001411	*		
		Cubic	–0.00003	0.000013	–0.000052	–0.000002	*		
Biceps	28	Intercept	0.99641	0.002123	0.992179	1.000647		0.000065	0.000021
		Linear	0.00048	0.000154	0.000176	0.000780	**		
Triceps	29	Intercept	1.00967	0.003569	1.002623	1.016726		0.000106	0.000039
		Linear	–0.00505	0.001504	–0.008011	–0.002097	***	0.000001	0.0000004
		Quadratic	0.00066	0.000201	0.000265	0.001054	***		
		Cubic	–0.00002	0.000008	–0.000039	–0.000008	**		
(B) Parameter estimates of the fixed and random effects in the anger condition of muscles on the left									
Trapezius	28	Intercept	0.99884	0.006495	0.985667	1.012014	a	0.000999	0.000279
		Linear	0.00049	0.000263	–0.000026	0.001009			
Deltoid	30	Intercept	0.99330	0.005088	0.983091	1.003500		0.000523	0.000150
		Linear	0.00098	0.000301	0.000389	0.001571	***		
Biceps	30	Intercept	0.99725	0.002661	0.991931	1.002570		0.000128	0.000038
		Linear	0.00038	0.000174	0.000041	0.000725	*		

Notes: *$p < .05$, **$p < .01$, ***$p < .001$. [a]$p = .062$.

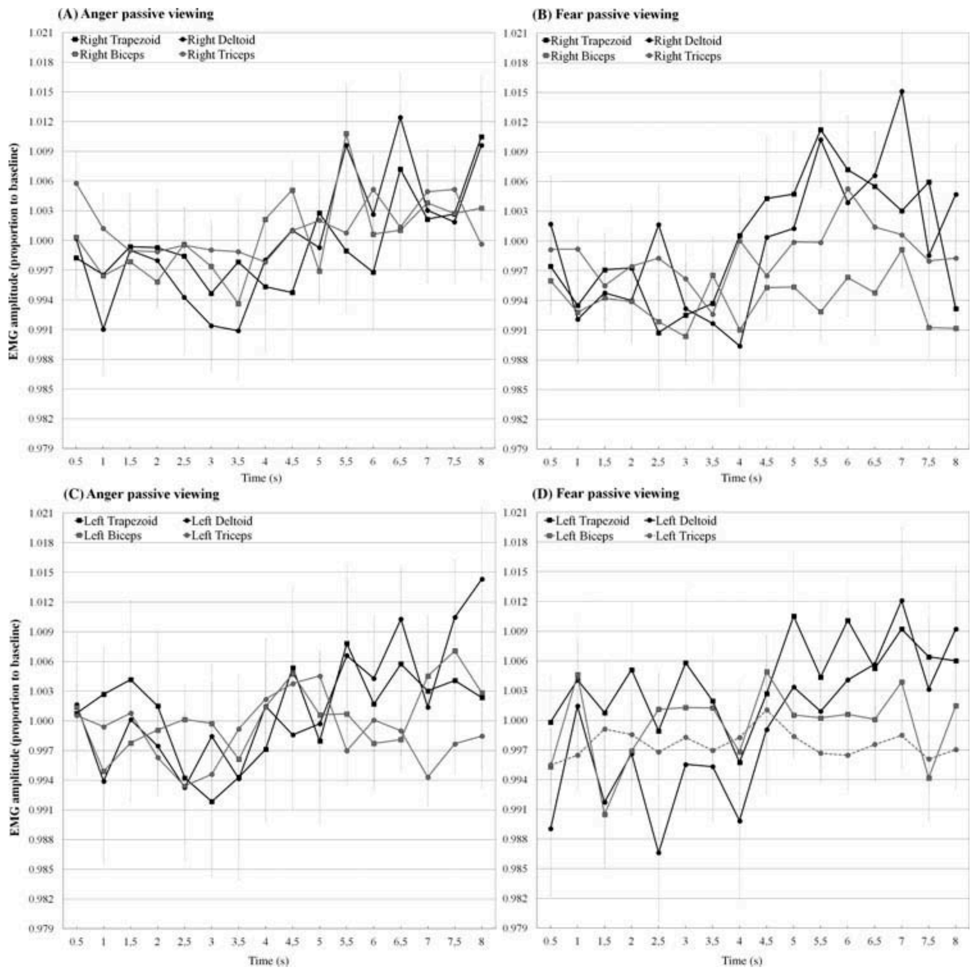

Figure 3. EMG amplitudes and standard errors of the mean during anger passive viewing on the right (A) and left (C), fear passive viewing on the right (B) and left (D). The first 3 s represent EMG activity during stimulus presentation.

the other muscles, this muscle does clearly respond to the perception of emotion, especially fear. This may be related to the function of the upper trapezius in posture stability, whereas it only plays a supporting role in moving the shoulders (Johnson, Bogduk, Nowitzke, & House, 1994). Also, trapezius activity is related to sympathetic arousal (Krantz, Forsman, & Lundberg, 2004) and is sensitive to cognitive stressors (Lundberg et al., 2002; Wijsman, Grundlehner, Penders, & Hermens, 2013). Furthermore, muscles in the neck are stimulated by areas related to gaze shifts and orienting such as the caudate nucleus (Akaike, Ohno, & Tsubokawa, 1989) and superior colliculus (Corneil, Olivier, & Munoz, 2002), which are areas also involved in the perception of emotional body language (de Gelder, 2006).

It is interesting to note that all muscles are inhibited during stimulus presentation and activate only after stimulus offset. This may be a result of the interactive nature of the videos. An appropriate response to the person in the video can only be formulated at the offset of the video, because only then the whole emotional action of the other person is seen. Muscle activity inhibitions have been previously related to orienting responses, anticipation to events, or sound discrimination (Stekelenburg & Van Boxtel, 2001, 2002; Van Boxtel, Damen, & Brunia, 1996) but may also depend on the specific innervation of the muscle. The muscles in our study are differently innervated from facial muscles and from each other. The trapezius is innervated by the spinal accessory nerve (Walker, 1990), the anterior deltoid and triceps by the axillary nerve (de Sèze et al., 2004) and the biceps brachii by the musculocutaneous nerve (Schünke, Schulte, Schumacher, Ross, & Lamperti, 2006). Inhibitory responses can be very specific to the situation and vary per muscle within the same person, for example, perceiving pain in another

TABLE 4
Parameter estimates, 95% confidence intervals, and significance levels of the best fitting model for each muscle on the (A) right and (B) left in the fear passive viewing condition

			Fixed parameter					*Random parameter*	
	N		*b*	*SE b*	*95% CI (L)*	*95% CI (U)*		*Variance*	*SE Var*
(A) Parameter estimates of the fixed and random effects in the fear condition of muscles on the right									
Trapezius	26	Intercept	1.005194	0.006722	–0.013098	–0.001707		0.000281	0.000087
		Linear	–0.007402	0.002897	0.000504	0.002037	**		
		Quadratic	0.001271	0.000390	–0.000083	–0.000023	**		
		Cubic	–0.000051	0.000015	–0.013098	–0.001707			
Deltoid	30	Intercept	0.992060	0.003511	0.985030	0.999090		0.000234	0.000069
		Linear	0.000949	0.000221	0.000515	0.001383	***		
Biceps	29	Intercept	0.998577	0.004067	0.990547	1.006607		0.000129	0.000049
		Linear	–0.003026	0.001725	–0.006417	0.000365		0.000001	0.0000004
		Quadratic	0.000443	0.000231	–0.000011	0.000898			
		Cubic	–0.000018	0.000009	–0.000035	0.000000	*		
Triceps	30	Intercept	1.003527	0.003957	0.995726	1.011327		0.000091	0.000040
		Linear	–0.003778	0.001766	–0.007248	–0.000307	*	0.000001	0.000001
		Quadratic	0.000556	0.000236	0.000091	0.001020	*		
		Cubic	–0.000021	0.000009	–0.000039	–0.000003	*		
(B) Parameter estimates of the fixed and random effects in the fear condition of muscles on the left									
Trapezius	28	Intercept	0.999970	0.004896	0.990106	1.009834		0.000489	0.000142
		Linear	0.000474	0.000263	–0.000043	0.000991	[a]		
Deltoid	30	Intercept	0.988826	0.004600	0.979611	0.998040		0.000410	0.000119
		Linear	0.001195	0.000283	0.000638	0.001751	***		

Notes: *$p < .05$, **$p < .01$, ***$p < .001$, $^{a}p = .07$.

person’s hand causes corticospinal inhibition in the corresponding own hand, but excitability in the opposite hand (Avenanti, Minio-Paluello, Sforza, & Aglioti, 2009).

It was previously established that the stimuli used in the current study activate brain areas involved in both the perception and execution of emotions and actions, such as the amygdala, insula, supplementary motor area, inferior frontal gyrus, cerebellum, and premotor areas (Grèzes et al., 2007; Pichon et al., 2008, 2009, 2012). Automatic responses of muscles in the body may originate from brain areas involved in action preparation, the expression and perception of emotions, social interactions, and threat (Carr et al., 2003; Hennenlotter et al., 2005; Leslie et al., 2004) through connectivity of the motor cortex, basal ganglia, amygdala, the brain stem, and the spinal cord (Liddell et al., 2005; Morecraft et al., 2007; Sagaspe, Schwartz, & Vuilleumier, 2011; Takakusaki, Saitoh, Harada, & Kashiwayanagi, 2004; Tamietto & de Gelder, 2010).

The first and most important aim of the current study was to create a BACS that describes what action units are used for expressing emotional expressions. This article is only the first exploration in this direction, and it was decided to start with only fearful and angry expressions. Thus, one methodological issue of the current article pertains to the lack of a comparable baseline condition. In contrast to the use of still photographs of faces, it is very difficult to find a suitable neutral condition with the same movement components when it comes to dynamic bodily expressions. One option is to use neutral actions performed with the arms, such as hair combing, making a call, or lifting a glass to the mouth. However, in the context of the current stimuli in which people opened a door, this would be very unnatural. Unfortunately, the neutral versions of these videos vary greatly from the angry and fearful version with regard to movement and emotional intensity (Pichon et al., 2008), which we felt is unacceptable for the current study. Another option is to use stimuli of people performing an emotion without any context or direction. It was decided to use the stimuli of a person opening a door for two reasons. First, from the perspective of the participant, it is more interactive (as if the person is responding to you), which is a more relevant and natural situation. To illustrate, Grèzes et al. (2013) found stronger corrugator activity in response to an angry bodily expressions when they were directed to the participant than when they were not. Even more so than facial expressions, bodily expressions and social interactions alert the perceiver to action tendencies of the other and in turn prepare the observer for action. Recently, it has been argued that social interactions should be studied more predominantly in neuroscience (Schilbach et al., 2013).

Another problem with bodily expressions, as compared with facial expressions, is the variation in the number of possible ways to express a certain emotion. In this study, the participants imitated the actors in the videos. Even though the actors themselves expressed their emotion freely, and all stimuli showed varied ways of expressing anger and fear, it would not only be interesting but also necessary to see if these results are replicated if participants are asked to express emotion freely themselves. Additionally, information on which trajectories are made in space and time with what limbs, for example measured with accelerometers, would provide a descriptive level of movement in concordance with the EMG data. One such coding system based on microdescriptions of body movements has recently been developed (Dael, Mortillaro, & Scherer, 2012), which can be of use for describing the articulation of body movement over time. A negative aspect of such a system is the time-consuming and complicated process. Another coding system, the AutoBAP (Velloso, Bulling, & Gellersen, 2013), is automatic but requires a motion capture lab. Additionally, these systems do not provide information on muscle activity, and in order to be able to record activations not visible to the naked eye, it is necessary to also have a BACS.

The second aim of the study was to assess whether it is possible to detect small changes in muscle activity without any overt movement. However, without the foundation of a BACS, it is difficult to infer solid conclusions from the results, such as whether the activations found in the passive viewing experiment are the result of processes related to mimicry of the seen movements or whether the same results will be found when participants are subjected to faces, audio, or other non-body-related emotional stimuli such as animals or scenes. Based on previous work related to facial EMG, it can be expected that these activations do not merely reflect a motor mapping of the observed movements and that bodily muscles will also activate in response to these situations (Bradley & Lang, 2000; Dimberg et al., 2000; Grèzes et al., 2013; Hietanen et al., 1998; Kret et al., 2013; Magnée, Stekelenburg, et al., 2007; Tamietto et al., 2009).

In short, once a BACS is established, it opens up a new array of possibilities to gain further insight into the mechanisms of emotional processing, social cognition, or empathy. Furthermore, it may prove an interesting tool for research into, and diagnostic tools for, several psychological or neurological disorders such as adolescents with behavioral disorders, autism, anxiety, or developmental disorders (Bakker, Tijssen, van der Meer, Koelman, & Boer, 2009; de Wied, van Boxtel, Matthys, & Meeus, 2012; Magnée, de Gelder, van Engeland, & Kemner, 2007; Oberman, Winkielman, & Ramachandran, 2009). Recently, an interesting study showed that joy and fear can spread from person to person as measured with EMG, even when subjects further removed from the initial person displaying the emotional cues were not able to overtly identify the emotion (Dezecache et al., 2013). In addition, there is an increasing interest from other fields (Kleinsmith & Bianchi-Berthouze, 2007; van den Broek, 2012), such as emotion technology, affective computing, artificial intelligence, ICT, or biomedical technology, wanting to incorporate knowledge about physiological responses of the body and their relationship to the emotion of the user in the creation of brain computer interfaces, robots, game characters or virtual reality avatars, software that is able to automatically assess emotional expressions, e-learning or e-therapy, or even day-to-day equipment that is tuned to the emotion of the user. Also, knowledge about how body posture influences the state of another can benefit experts in other professions in which successful social interaction is crucial, i.e., teachers, psychologists, or police (see Kleinsmith & Bianchi-Berthouze, 2013 for an extensive review). The creation of a BACS would in this regard be very complementary to the FACS, and technological developments enable the use of EMG in these settings, with wireless and easy-to-use systems suitable for a non-laboratory environment already available. Last, bodily expressions have several advantages compared to facial expressions—they are more interactive, directional, can be recognized from longer distances, and do not automatically convey identity information (de Gelder, 2009).

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