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SKIN CONDUCTANCE RESPONSE AND FACIAL EXPRESSIONS OF EMOTIONS

Master´s thesis

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Running head: Skin conductance response and emotional expression

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Skin conductance response and facial expressions of emotions

Abstract

Emotional expressions provide strong signals in social interactions and can function as emotion inducers in a perceiver. The skin conductance response (SCR) is an objective, transient indication of autonomic nervous system arousal in response to an external emotional stimulus. The current study examined 118 healthy participants that were presented with three different types of emotional stimuli (Ekman's faces, verbal cues and IAPS pictures). The motions presented in the current experiment were six basic emotions (anger, happiness, sadness, fear, disgust, surprise) and a neutral stimulus. The participants were asked to either mirror or express the presented emotion or suppress or exaggerate facial expression response to the pictorial stimuli while their electrodermal activity was recorded. As expected, affective stimuli elicited increased arousal measured by SCR, compared to the neutral stimuli. Modulating facial emotion expressions (in suppressing and exaggerating conditions) also resulted in higher SCR scores. Self-reported ratings in the exaggeration and suppression conditions mostly did not align with SCR scores but reflected a more robust emotion specific arousal pattern than SCR arousal. Arousal-based emotion differentiation patterns were more noticeable in lower arousal conditions, like mirroring or expressing facial emotions without a regulation task. Verbal stimuli did not result in lower SCR scores than facial stimuli. Since conscious effort to modulate emotional face expressions resulted in higher SCR scores, but did not fully align with self-reported ratings on arousal, it was concluded that SCR does not reflect emotion specific arousal, but is an important tool to investigate in emotional regulation studies.

Keywords: skin conductance response, emotion facial expressions, response modulation, suppression, exaggeration, arousal patterns.

Naha galvaanililise reakstiooni faasilise komponendi seosed emotsioonide näoväljendustega

Kokkuvõte

Naha galvaaniline reaktsioon on vahetu ja lihtsalt mõõdetav sümpaatilise närvisüsteemi aktiivsuse näitaja. Emotsionaalse stiimuli ilmnemisel kasvab autonoomse närvisüsteemi erutus ning suureneb higistamine, mille käigus tõuseb naha elektrijuhtivuse võime (SCR ehk faasiline komponent). Käesoleva uurimistöö eesmärgiks oli uurida, kuidas emotsioonide näoväljendused ning nende sihilik kontroll mõjutavad naha elektrijuhtivust, ning kas naha elektrijuhtivus omakorda eristab emotsioone ja neid esile kutsunud tingimusi. Valim koosnes 118st tervest vabatahtlikust, kellele näidati kolme erinevat tüüpi emotsionaalseid stiimuleid - Ekmani näopilte, emotsioone väljendavaid sõnu (kirjalikult), ning IAPS andmebaasi pilte. Uurimuses kasutati kuut baasemotsiooni (viha, rõõm, kurbust, üllatust, hirmu, vastikus) ning lisaks neutraalsust. Osalejatel paluti esitatud emotsioone kas peegeldada, väljendada, üle väljendada või varjata. Samal ajal mõõdeti nende naha elektrilist aktiivsust ning seejärel paluti hinnata kogetud emotsiooni intensiivsust. Kirjalikult esitatud verbaalsed stiimulid tõstsid SCRi rohkem võrreldes näopiltidega. Tugevamad emotsioonid tõstsid ootustepäraselt naha elektrijuhtivust. Emotsionaalsete näoväljenduste sihilik kontroll (varjamine ja üle väljendamine) tõstsid SCRi kaudu mõõdetud erutust, eristades neid tingimustest, kus näoväljendused olid loomulikumad. Suurenenud SCRi kaudu mõõdetud autonoomse närvisüsteemi erutus ei olnud täielikult kooskõlas enesekohaste hinnangutega. Enesekohased hinnangud emotsioonide intensiivsusele varjamise ja üle väljendamise tingimustes eristasid emotsioone omavahel oluliselt paremini, SCR peegeldas pigem üldist ärevust, kuid ei eristanud oluliselt emotsiooni-spetsiifilist aktiivsust.

Märksõnad: naha galvaaniline reaktsioon, naha elektrijuhtivus, emotsioonide näoväljendused, emotsionaalse reaktsiooni modulatsioon, emotsiooni-spetsiifiline aktiivsus.

The study of human emotion is a fascinating and cross-disciplinary field of research. Whilst generally studied in the realm of psychology, it has vastly been extended to other disciplines such as neuroscience, product and experience design, and computer science in the past 20 years (Gatti et al., 2018). The processing of emotional facial expression is central to human interaction and has substantial effects on behaviour and affective state (Bourke et al., 2010). Human emotional reactions to stimuli delivered by different sensory modalities are a topic of interest for many disciplines, from Human-Computer-Interaction to cognitive sciences (Gatti et al., 2018). Emotional responses consist of a complex interplay between multiple response systems like cognition, behavior, and physiology (Bos et al., 2013). Emotional and cognitive processes evoke patterned changes in one's bodily state that may signal emotional states to others. This dynamic modulation of visceral state is neurally mediated by sympathetic and parasympathetic divisions of the autonomic nervous system. Electrodermal activity is an interesting autonomic measure of psychophysiology in that it reflects sympathetic neural responses independent of direct parasympathetic control or circulating factors such as adrenaline (Critcley, 2009). Skin conductance responses, as components of electrodermal activity, are one of the most frequently used peripheral physiological markers; presumably because they are exclusively activated by the sympathetic nervous system and because they are robust against voluntary modulations. Thus, skin conductance response can be assumed to provide an excellent measure for the elicitation of emotional arousal (Dawson et al., 2007; Jürgens et al., 2018).

Somatic input and emotions

The importance of peripheral signals for mental functions — and especially emotions — has been identified by psychologists early on. Emotions involve a somatic component and act on bodily states (Damasio, 2001); thus, these responses constitute a critical element in the emotional experience overall (Grandjean et al., 2008). One of the first and major theories of emotions — the James-Lange theory of emotion (James, 1890) — suggests that physiological changes, including expressive behavior, facial expressions and peripheral, visceral responses (heart rate, emotional sweating, etc.) are actually temporally preceding what we call emotions. In fact, emotions could partially be an interpretation of the peripheral changes. Walter Cannon (1927) strongly criticized the theory, with one argument being that visceral responses are too slow to allow for quick responses to the environment. It seems that both theories are to a great extent correct, but the main point to consider here is that peripheral responses (including skin conductance response, or SCR) could act as messengers based on which emotions are formed. Visceral responses constitute an essential (though not necessarily causal) component of the emotional response. This idea was further analyzed and supported by — the more anatomically valid — MacLean's ideas on the role of the limbic system on emotions (MacLean, 1949), which suggests that emotions necessarily integrate signals from the environment as well as the body to guide behavior (Cristopoulus et al., 2016). As such, one can infer that bodily responses are an almost essential part of the emotional experience that could bias cognition and, thus, behavior. Specifically, these bodily responses act as somatic markers that can bias behavior vis-à-vis meaningful environmental stimuli (Bechara & Damasio, 2002; Bechara et al., 2005; Damasio, 1996). Damasio proposed a distinction between emotions and feelings whereby emotions are "collections of responses" corresponding to external and measurable reactions expressed via the musculoskeletal system, as well as internal and measurable reactions of neurovegetative, neurohormonal, and neuroimmune systems controlled by the central nervous system (Damasio, 2000). Feelings, however, correspond to the subjective experience of these emotional responses (Damasio, 1999; D´Hondt et al., 2010). Despite different theories of emotions proposed over the years, there seems to be the common understanding that emotional states are characterized by physiological and cognitive responses to clearly identifiable stimuli (Gatti et al., 2018).

Electrodermal activity and skin conductance response

Electrodermal activity (EDA), formerly called the galvanic skin response, has been one of the most widely used response systems in the history of psychophysiology. EDA provides a direct and undiluted representation of sympathetic activity (Dawson et al., 2007). Electrodermal activity is more sensitive to variations in emotional arousal (i.e. calming or stimulating) rather than to valence (i.e. pleasant or unpleasant) (Khalfa et al., 2002). Electrodermal activity is divided into tonic and phasic phenomena. The tonic level of skin resistance or conductance is the absolute level of resistance or conductance at a given moment in the absence of a measurable phasic response, and it is referred to as skin conductance level (SCL). Superimposed on the tonic level are phasic decreases in resistance (increases in conductance) referred to as SCR - skin conductance response (Dawson et al., 2007). EDA — with SCR being a part of EDA — is a biomarker of arousal with well-known psychophysiological functioning (Cristopoulus et al., 2016). In other words, skin conductance response is the mostly uncontrollable and unconscious process through which the skin momentarily acquires better conductivity properties due to an increase in perspiration. The neural control of eccrine sweat glands is entirely under sympathetic control (Dawson et al., 2007). Skin conductance is a slow reacting measure based on the alterations of electrical properties of skin after sweat secretion (Jürgens et al., 2018). At the moment of stimulation, more sweat glands conduct electricity to the skin. The time series of skin conductance can be characterized by a slowly varying tonic activity (SCL) and a fast varying phasic activity (SCRs). SCRs may reflect stimulus-specific responses or non-specific responses and show a steep incline to the peak and a slow decline to the baseline. The succession of SCRs usually results in a superposition of subsequent SCRs, as one SCR arises on top of the declining trail of the preceding one. SCRs that occur in a predefined response window (typically 1–3 or 1–5 seconds after stimulus onset) are attributed to the stimulus (Benedek & Kaernbach, 2010; Dawson et al., 2007). In other words, skin conductance responses are phasic, short-term responses that reflect arousal and are used to assess non-conscious responses to external emotional stimuli (Banks et al., 2014, Cristopoulus et al., 2016). The stimuli to which the SCR is sensitive are wide and varied. The range of stimuli that elicit larger SCRs include those that are perceived to be novel, surprising, intense, significant, or emotional (Dawson et al., 2007) with a strong emphasis on the significance or emotional quality of stimuli (Öhman & Wiens, 2003, Dindo & Fowles, 2008). The occurrence of SCR is generally quite discriminable: on a single presentation of a stimulus, one can determine by quick inspection whether SCR occurred (Dawson et al., 2007). Topologically, emotional sweating is more profound in palms, where eccrine sweat gland density is greatest (Cristopoulus et al., 2016).

Emotion- specific arousal patterns

EDA reflects general states of arousal that are regulated by the activation of the autonomic nervous system (ANS) through sweat gland stimulation (Innocente et al., 2020). The idea that different emotions have different patterns of attendant ANS activity grows directly out of the evolutionary model, where emotions help the organism efficiently deal with a set of common problems that are critical for species survival (Levenson, 2014). The sympathetic nervous system (SNS), a part of ANS, stimulates a body's flight or fight response, thus formulating a relationship between emotional arousal and sympathetic activity (Das et al., 2016). Despite the individual differences within perceived arousal and valence of emotions (Kuppens, 2008), some general differentiations have been made within emotion research. Russell (1980) proposed a circumplex model of emotions (*Figure 1 below*), where the horizontal dimension, also called valence, corresponds to the emotions of pleasure / displeasure, the vertical dimension, known as arousal, corresponds to the emotions of excitation-relaxation. Surprise, fear, anger, disgust, and happiness (regardless of the opposite valence) have been classified as highly arousing emotions. Sadness is considered a low arousal emotion (Bustamante et al., 2015). The various arousal patterns emotions are claimed to elicit is a good reference point for examining skin conductance responses in different conditions.

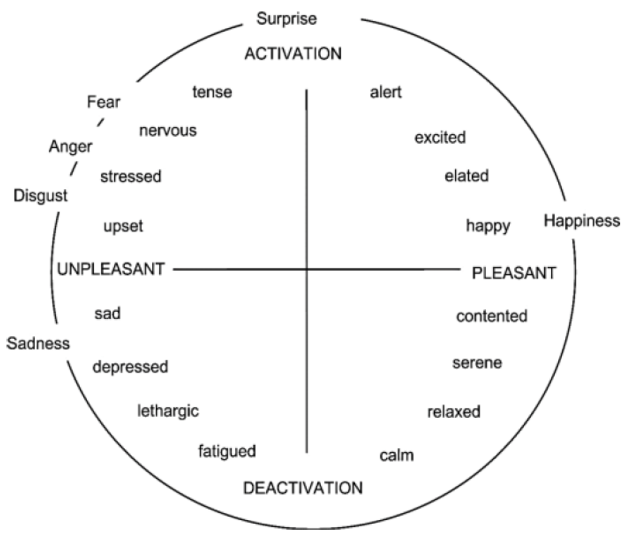


Figure 1. *Circumplex model of emotions (Russell, 1980).*

Stimulus domain differences

Two main types of visual emotional stimuli have usually been employed in the study of affect-related processes: verbal (e.g., single words or sentences) and pictorial (e.g., facial expressions or emotional scenes) (Hinojosa et al., 2009). Research in the comparability of emotional effects across different stimulus classes (emotional words, pictures, and facial expressions) remains limited (Bayer & Schacht, 2014). Not as much physiological research has been devoted to the role of emotional content in language processing as in the processing of other visual stimuli. An important and recurrent question is whether both types of visual stimuli (verbal vs scenic) are equally capable of inducing emotional reactions (Hinojosa et. al., 2009).

Emotional facial expressions should be particularly well suited to elicit evolutionarily grounded motivational responses (Alpers, 2011). While the meaning of most scenes can only be deciphered when several elements are integrated, faces are processed holistically, i.e. using relatively more minor part decomposition than other types of objects (Farah et al., 1998, Alpers, 2011). Facial expressions are also generally thought to be biologically rooted (Dimberg et al., 2000), comparable across cultures (Ekman et al., 1969), and to evoke emotional responses in everyday life (Alpers, 2011). The accurate identification and interpretation of emotional events in the environment is a crucial component of social functioning, and increases the organism's chances of survival. To investigate individuals' subjective and physiological responses to emotional stimuli, a standardized set of over 600 emotional pictures has been developed: the International Affective Picture System - IAPS (Lang et al., 2005). These stimuli are capable of eliciting characteristic patterns of physiological responses in healthy individuals (Armhein, 2004). In contrast to affective pictures and emotional facial expressions, the emotional significance of written words is ontogenetically learned and symbolic (Schaht & Sommer, 2009). Because of the presumed evolutionary significance of fast emotion perception in faces (Schupp et al., 2007) and natural scenes (Öhman et al., 2001), their emotional content has been suggested to automatically catch attention and to be preferentially processed within a few 100 ms (Palazova et al., 2013) in event-related brain potential studies. The time delay between the onset of the eliciting stimulus and onset of the response (latency) is between 1 and 3 seconds. The response typically takes another 1 to 3 seconds to reach its peak (rise time). Thus, the SCR is a relatively slow-moving response compared to other physiological responses, such as event-related cortical potentials (Dawson et al., 2011). Rapid and preferential responses to these stimuli are thought to be biologically adaptive as emotionally intense stimuli usually represent things that, if encountered in reality, would either threaten or promote one's well-being (Kissler et al., 2009). In the verbal domain, evidence is more controversial (Palazova et al., 2013). A theoretical perspective concerning the cognitive processing differences between picture and word suggests that words require additional processing before they access to its emotional aspects, while picture processing does not (Glaser & Glaser, 1989). The extraction of emotional significance from words is usually assumed to be based on semantic knowledge (e.g., Kissler et al., 2007; Schacht & Sommer, 2009), whereas for evolutionarily prepared stimuli (e.g., facial expressions, affective pictures), it may be based on perceptual features (Rellecke et al., 2011). This additional processing involves top-down modifying, which generates the psychological representation to help us access emotional aspects of stimuli through mental imagery, propositions, or both (Yuan et al., 2019). It has been pointed out that pictorial stimuli are associated with higher levels of emotional arousal than verbal emotional material (Carretié et al., 2008; Kissler et al, 2006). These assertions are based in part on theoretical views that deny any role for verbal material in the evolution of emotion-related neural systems and assume that the processing of verbal material is culture-mediated. It is also noteworthy, however, that the majority of the studies have looked into the processing of verbal or pictorial emotional stimuli separately, across a wide variety of tasks and experimental parameters (Hinojosa et al., 2009). Little to no evidence has been found comparing SCR in reaction to written words vs other visual stimuli. More research has been done on the effects of verbalizing the emotional experience or reacting to auditory stimuli. We found no evidence of SCR data response comparisons between written verbal stimuli and visual stimuli in the same analyses. Similar physiological research that compares emotional reaction to written words vs other visual stimuli based on event-related electrocortical responses (ERP) has pointed out that words in general are reported to be less capable of triggering emotion effects in ERP, although a number of studies have reported similar activation patterns to visual stimuli (Bayer & Schacht, 2014). This difference is explained with a supposedly lower level of arousal for symbolic stimuli, i.e., words, which in turn elicit weaker ERP arousal responses (Bayer & Schacht, 2014; De Houwer & Hermans, 1994; Hinojosa et al., 2009). A similar assumption is supported by reduced emotion effects in facial muscle activity for words as compared to pictures and sounds (Larsen et al., 2003).

Response modulation

Emotion regulation has been broadly defined as "the initiation of new, or the alteration of ongoing, emotional responses through the action of regulatory processes" (Ochsner & Gross, 2005). Emotional responses are adaptive responses to an eliciting stimulus, including action tendencies, bodily responses, behavioral responses and a change in subjective feeling (Brosch et al., 2010). Emotions do not force us to respond in certain ways; they only make it more likely we will do so. This malleability permits us to regulate our emotional responses (Gross, 2002). James Gross (1998; 2002) separated response strategies into ‘‘antecedent’’ and ‘‘response-focused’’ categories, with the former being employed prior to the enactment of emotion response tendencies (i.e., affective, behavioral, and physiological change) whereas the latter are aimed at modulating emotional output. In other words, response-focused strategies, including affective suppression and exaggeration, are attempts to modulate behavior once an emotion has commenced (Demaree et al., 2004). Increased sympathetic activation has been observed repeatedly in studies of response focused strategies (Demaree et al., 2006; Gross 1998, 2002; Goldin et al, 2008).

Although subjective emotional states and physiological responses usually correlate during emotion experiences, attempted emotion suppression can cause dissociation between subjective and physiological responses (Ohira et al., 2005). Expressive suppression is a strategy directed toward inhibiting behaviors associated with emotion-expressive behavior (e.g., facial expressions, verbal utterances, gestures) (Gross, 2002). Suppression decreases behavioral expression, but fails to decrease emotion experience (Gross, 1993; Gross, 2002; Goldin, 2008). As measured by finger temperature, finger pulse amplitude, and skin conductance level, subjects asked to suppress their facial response experienced significantly greater sympathetic activation relative to those in the other conditions; similar findings have been found as a result of expressive exaggeration (Demaree et al., 2004, 2006). It is noteworthy that whereas suppressing negative emotion-expressive behavior has no discernible impact on negative emotion experience (e.g., disgust, sadness, embarrassment), suppressing positive emotion-expressive behavior does have an impact on positive emotion experience (e.g., amusement) (Gross, 2002).

Present study

The current thesis is a part of a larger research project that collects multimodal data (EEG, EDA and video recordings) in order to create the first systematic multimodal database of facial expressions expressing or hiding felt emotion. The aim of the project is to develop a new neural network technique that would allow artificial intelligence to automatically detect emotional states. The outcome of this research is important from a psychological research perspective as well as for a better understanding of human-machine interaction. Another research paper was also written on the current experiment (Juuse, 2020), focusing on visual and verbal information and emotion processing based on EEG and self-assessment. The goal of the current paper is to analyze skin conductance response differences within different stimulus domains: affective pictures, emotional facial expressions and written words, and to investigate how the response focused expression modulation affects arousal measured via skin conductance response, specifically focusing on the phasic component of electrodermal activity.

Based on the previously described research, it was hypothesized that

1. Higher arousal emotions also elicit higher skin conductance response in different experiment conditions.
2. Response focused expression modulations as suppression and exaggeration increase arousal measured by skin conductance response.
3. Skin conductance response is higher in response to facial stimuli versus verbal cues.

Method

Participants and procedure

The data used in the current thesis was collected between 2018-2019 as a part of a larger research project "Recognizing expressed and hidden emotions by face and electrophysiological signals from the brain" led by professors Kairi Kreegipuu, PhD (Institute of Psychology, University of Tartu) and Gholamreza Anbarjafari, PhD (Institute of Technology, University of Tartu). Another research paper, focusing on visual and verbal information and emotion processing based on EEG and self assessment, was also written based on the current experiment (Juuse, 2020).

The experiment took place at the Laboratory of Experimental Psychology at the University of Tartu May 2018 through May 2019. Participants were gathered from university mailing lists and experimenters' personal social media pages. Participants were briefly informed about the general aim of the study via email prior to attending the experiment. They were also asked to fill out EE.PIP-NEO-300-240 personality self-questionnaire (Mõttus et al., 2006) to evaluate traits based on the Five-Factor model of personality; and PANAS (Positive and Negative Affect Schedule; Watson et al., 1988) self-report questionnaire to assess the general mood of the participant within the last two weeks (Juuse, 2020). The duration of one session (including pre- and post-procedures) was approximately 3 hours and varied based on the answering speed of the participant. Due to the focus of current work, the EEG recordings, personality traits and positive/negative affect will not be analyzed further in this thesis. For the description of the full original experiment procedure see Juuse (2020).

The final sample used for analysing skin conductance responses consisted of 118 healthy adults (71 women, 47 men) within the age range 18-49 and a mean age of 25.19 (*SD* = 6.36). The initial sample consisted of 119 healthy volunteers, but due to technical artefacts observed in a trial of electrodermal activity recording, one participant was excluded. Three categories based on the participants' primary language were differentiated: 91 Estonian, 17 Russian and 10 English speaking. 107 participants reported themselves to be right-handed, 8 left-handed and 3 ambidextrous. Preliminary regression analyses on the SCR scores of the different groups showed no significant differences and it was concluded that all groups can be included in the final report.

The participants were naive to the aim of the experiment, to the pictures used and were briefed with the aims of the study after completing the tasks (Juuse, 2020). Each participant signed a written consent form agreeing to the future uses of the data for educational scientific purposes. The study was approved by the Research Ethics Committee of the University of Tartu and carried out in accordance with the Declaration of Helsinki.

The measures of EEG, skin conductance response and facial expressions were conducted in an electrically shielded quiet room. Recordings were made with the BioSemi ActiveTwo (BioSemi, Amsterdam, The Netherlands) system at a sampling rate of 512 Hz. Skin conductance data was collected using two electrodes covered with SignaGel, a highly conductive, multi-purpose electrolyte placed at the volar surface of the index and middle fingers of the participants' non-dominant hand.

Stimuli

The experiment consisted of four parts:

1. Mirroring emotional expressions presented on screen, based on Ekman's (Ekman & Rosenberg, 1997) facial stimuli (anger, disgust, happiness, neutral, sadness, surprise, fear).

2. Expressing emotional words (verbal cues) shown on screen (anger, disgust, happiness, neutral, sadness, surprise, fear).

3. Exaggerating emotional expressions in response to IAPS images (anger, disgust, surprise, sadness, happiness, fear, neutral).

4. Suppressing emotional expressions in response to IAPS images (anger, disgust, surprise, sadness, happiness, fear, neutral).

Pictures of Ekman's facial expression pictures were used for the mirroring part of the experiment (Ekman & Rosenberg, 1997). The visual images used for this experiment included two sets of digitized versions of 7 color pictures selected from the International Affective Picture System (IAPS; Lang, 2005) and Ekman's facial expressions (Ekman & Rosenberg, 1997). The stimuli from IAPS were chosen on the basis of their multidimensional normative ratings (Libkuman et al., 2007). The slide numbers of the pictures used in the experiment were the following 8420, 9045, 9561, 6821, 3063, 9405, 7010, 1999, 7502, 3350, 6313, 9300, 6230, 7705. The IAPS has been used to provide abundant insight into the dimensional aspects of emotion (Mikels et al., 2005). The standardized set of IAPS pictures has been rated in terms of their ability to induce arousal changes and correlated with viewer's skin conductance changes, providing physiological validity to subjectively reported emotion induction and eliciting short-lived affective responses (Britton et al., 2006; Bos et., al 2013).

Each stimulus was presented on screen for 6 seconds, preceded by a black and white grid for the duration of 500 ms. The participant was then asked to respond to a self reported question (as illustrated in Figure 2).

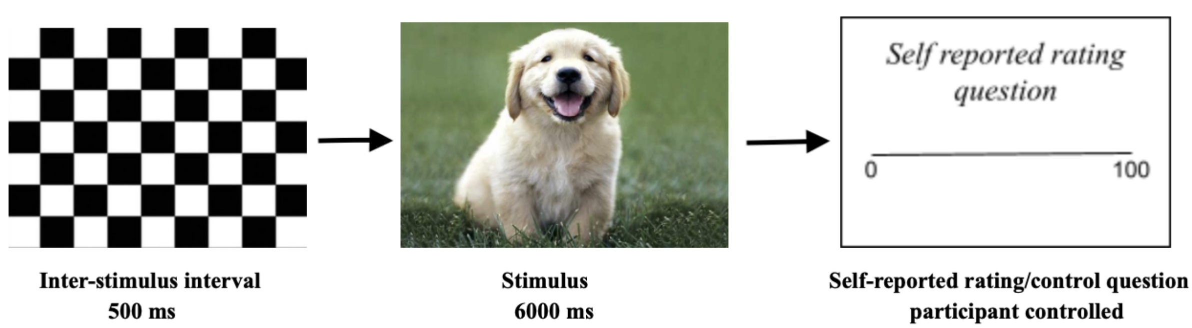


Figure 2. *The general set-up of a single visual condition trial. The picture presented above is an illustrative copyright free stock photo and was not used in the experiment.*

A single trial consisted of 7 emotional stimuli presented in a random order. Each participant completed 6 repetition blocks (7 emotions x 6 repetitions). In the first part the participant was asked to mirror facial expression pictures (Ekman's set) as depicted on the screen and rate their own emotional expression on a sliding scale 0-100 *("How well do you think you* *expressed this emotion?")*. In the second part, a written target word (verbal que) was shown to the participants. They were asked to express the emotion and to rate the difficulty of the task on a sliding scale from 0-100*("How well do you think you expressed this emotion?").* Sets of 7 emotions and 6 repetitions were used for the facial and verbal conditions of the experiment (7 emotions x 6 repetitions). In the third and fourth part of the experiment the participants were shown various IAPS images on screen. They were then asked to concentrate on the emotion that the scene elicited as much as possible and to either express the emotion in their face as clearly and expressively as they can (exaggeration condition) or to hold back any facial expressions (suppression condition). Every IAPS stimulus was followed by one out of three questions: either "*a) How intense was the emotion you felt?"* rated on a sliding scale 0-100; "*b) How negative/positive did you feel during the trial*?" rated on a sliding scale -100 to +100 or "*c) How many main objects were there in the last slide?"* rated by sliding left for one and right for more than one object. Question c was used as a control to observe whether the participants were giving meaningful answers to questions about the stimuli (i.e., whether or not they were paying attention to the task at hand). Two different sets of IAPS pictures were used for the last two parts of the experiment (2 sets x 7 emotions x 5 repetitions).

Preprocessing

Skin conductance data was analyzed using the Matlab based software LedaLab V3.4.9 (Benedek & Kaernbach, 2010). Data was downsampled to 16 Hz and analyzed via Continuous Decomposition Analysis (CDA; Figure 2). CDA separates tonic and phasic skin conductance components, allowing to focus on the phasic, event-related activity only. The tonic component of EDA is expected to vary over relatively long periods of time while the phasic component of the signal, extracted from the raw data, is expected only to be tied to the eliciting events (Gatti et al., 2018). Based on the previous research (Benedek & Kaernbach, 2010), a response window ranging from 1 - 4 seconds after stimulus onset was considered to capture the essential response to the stimuli, taking into account the slow signal. Only activation stronger than 0.01 µS threshold was regarded as an event-related response (Bach et al., 2009; Benedek and Kaernbach, 2010). An averaged phasic driver within the response window was used as a measure for SCR.

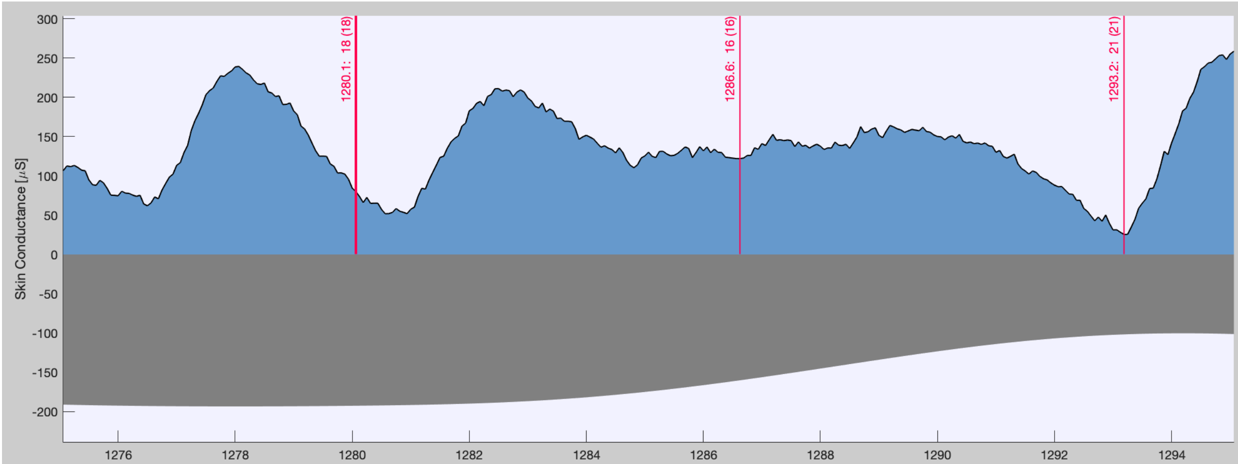


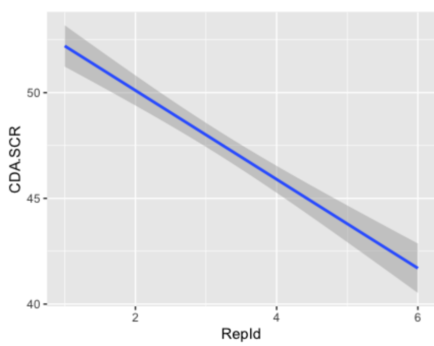
Figure 3. *Example of a skin conductance recording after applying continuous decomposition analysis (CDA) as displayed from the analysis software Ledalab. The blue area indicates the phasic component of the signal (SCR), while the grey area represents the tonic component (SCL). The red line indicates the stimulus appearance. Skin conductance levels are measured in μS.*

Prior to the analysis, SCR values of 0 were identified as errors and removed from the analysis (1% of the data points). Data points over 3 standard deviations above the overall mean were also identified as outliers and removed (2.1% of the data). Skin conductance response was measured in µS (micro-siemens). Root-square transformation was performed on SCR to make it roughly follow a normal distribution.

Analysis and results

The data was analyzed in R statistical environment version 4.0.2 (R Core Team, 2020). We used a linear mixed-effects regression as implemented in the *lme4* package (version 1.1.23; Bates et al., 2015) and *lmerTest* package (version 3.1.3, Kuznetsova et al. 2017), which applies Satterthwaite's method to estimate degrees of freedom and generates *p*-values for mixed models. Pairwise factor combinations within fitted linear models were tested with the *emmeans* package (Lenth et al., 2018) for *post hoc* comparisons. LME models have been recommended in psychophysiological research, because they offer several advantages over traditional ANOVA-based models, e.g., more efficient handling of missing data, more powerful tests that allow for modeling the error variance, and higher flexibility (Schwerdtfeger & Rosenkaimer, 2011).

SCR was included as the dependent variable, emotion, condition as well as the interaction between emotion and condition as variables of interest. Random intercepts by subject were included in the analyses as a random effect. Event number (marker) and repetition id were added to the model as control variables. Both the increasing number of event presentations and number of repetitions were negatively correlated with the value of SCR (see figures 4a and 4b below). Number of repetitions and event presentation number were added to the model as control variables to take these influences into account.



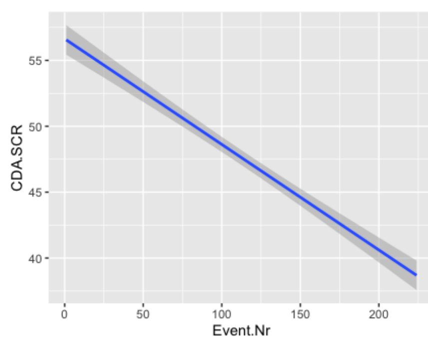


Figure 4a **Figure 4b**

Negative correlations between repetition (RepId) and event presentation number (EventNr) with skin conductance response scores (not root squared).

The final model is summarized in Table 1. The best model was received by using ANOVA comparisons between the baseline model including the random effects and control variables and a model including additional variables of interest. Forward fitting procedure was used while keeping the random effects fixed. The variables of interest were emotion with seven levels: neutral, anger, disgust, fear, happy, sad and surprise (neutral as the reference level), and condition with four levels: mirroring Ekman faces, expressing written words (verbal), exaggerated reaction to IAPS pictures and suppressed reaction to IAPS pictures. Interactions in the final model are presented in supplementary materials (Table 1a).

Table 1

Results of the linear mixed-effects model using neutral verbal stimulus as reference level

Scaled residuals				
Min	**1Q**	**Median**	**3Q**	**Max**
-4.29	-0.56	-0.11	0.38	5.57
Random effects				
Groups	**Name**	**Variance**	**SD**	
Participant id	Intercept	3.73	1.93	
Residual		4.16	2.04	
Fixed effects	**Estimate**	**SE**	***t***	
Intercept	7.51	1.99	37.66	***
Ekman faces	-7.70	1.16	-6.62	***
IAPS exaggerate	3.28	1.13	2.92	**
IAPS suppress	8.62	1.54	5.60	***
Anger	7.20	1.11	6.50	***
Disgust	1.22	1.10	1.11	
Fear	4.99	1.10	4.52	***
Happiness	3.57	1.11	3.22	**
Sadness	5.85	1.10	0.05	
Surprise	5.25	1.11	4.75	***
Event number	-1.16	9.14	-12.66	***
Repetition id	-8.51	1.05	-8.10	***

Note. * indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$. SE indicates standard error for the regression coefficient.

Emotions and SCR

As presented in Table 1 above, emotion had a significant main effect on SCR, which increased significantly more to anger ($\beta = 7.2$, $t = 6.50$, $p < .001$), fear ($\beta = 4.99$, $t = 4.5$, $p < .001$), happiness ($\beta = 3.57$, $t = 3.22$, $p = .001$), and surprise ($\beta = 5.25$, $t = 4.75$, $p < .001$) in comparison to neural stimuli. There was no significant difference between the neutral and disgust stimuli ($p > .05$) or between the neutral and the sad stimuli ($p > .05$).

Conditions and SCR

Different conditions had a significant main effect on SCR. When compared to verbal neutral stimuli, overall SCR was significantly lower while mirroring Ekman's faces ($\beta = -7.70$, $t = -6.62$, $p < .001$), and significantly higher while suppressing facial emotional reactions ($\beta = 8.62$, $t = 5.6$, $p < .001$). Exaggerating facial emotional reactions also resulted in a significantly higher SCR ($\beta = 3.28$, $t = 2.91$, $p = .001$) in comparison to verbal neutral stimuli. More specific results are shown in Table 1 above.

Emotion and condition interactions by post hoc analyses

The interactions between emotions and conditions were explored with pairwise comparisons performed using the *emmeans* package in R (Lenth et al., 2018) with degrees of freedom asymptotic using the Tukey method. Pairwise comparisons between all factor levels (condition) within 7 different different emotions revealed multiple statistically significant differences in SCR.

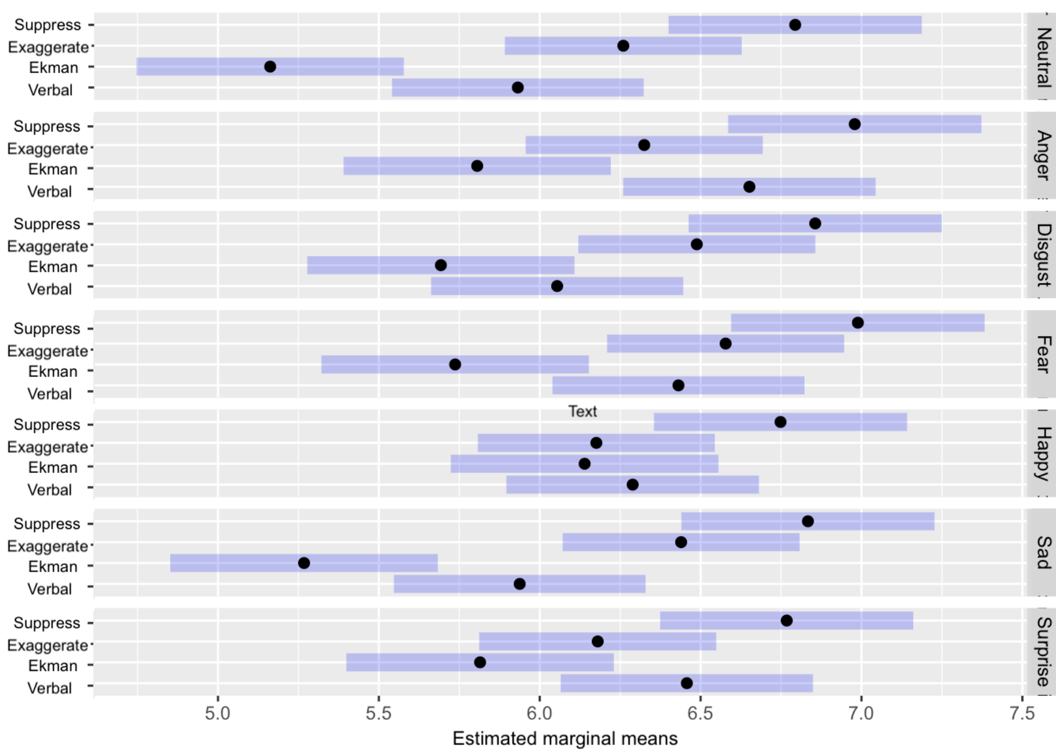


Figure 6. *Pairwise comparisons between estimated marginal means of the four factor levels (conditions) within seven emotions. The dot (●) indicates the estimated marginal mean of square rooted SCR scores and the brackets a 95% confidence level interval.*

Pairwise interactions within emotions

Figure 6 above illustrates the pairwise comparisons between SCR scores in the four conditions within all seven emotions.

Neutral emotion .Verbally experienced neutral emotion reflected lower SCR than suppressed neutral (z= -5.60; $p < .001$) and exaggerated neutral (z = -2.92; $p = 0.01$), but higher reaction than Ekman neutral (z = 6.62; $p < .001$). Exaggerated neutral emotion reflected slightly lower but significant SCR than suppressing (z = -5.02; $p < .001$). Ekman neutral elicited significantly lower SCRs than exaggerating ($z = -8.12$; $p < .001$) and suppressing neutral emotion ($z = -8.82$; $p < .001$).

Anger. No significant differences were found between verbal and suppressed anger. Verbally experienced anger resulted in higher SCRs than Ekman anger (z = 7.23; $p < .001$) and exaggerated anger (z = 2.88; $p < .05$). Ekman anger resulted in significantly lower SCRs than suppressed anger (z = -6.34; $p < .001$) and exaggerated anger (z = -3.84; $p < .001$). Exaggerated anger lowered SCR reaction than suppressed anger (z = -6.12; $p < .001$).

Disgust. Disgust in the verbal condition resulted in higher SCR in comparison to Ekman disgust (z = 3.09 $p = .01$), but significantly lower SCR compared to suppression (z = -5.20; $p < .001$) and exaggeration (z = -3.83; $p < .001$). Ekman disgust elicited significantly lower SCRs compared to suppressed disgust (z = -6.29; $p < .001$) and exaggerated disgust (z = -5.87; $p < .001$). Exaggerated disgust triggered lower SCR arousal compared to suppressed disgust (z = -3.46; $p < .01$).

Fear. No significant differences were found between SCR scores between verbal and exaggerated conditions. SCR score in verbal condition was higher compared to Ekman (z = 5.93; $p < .001$) and lower than the suppression condition (z = -3.61; $p = .002$). Ekman fear was also significantly lower than suppressed (z = -6.75; $p < .001$) and exaggerated fear (z = -6.21; $p < .001$). Exaggerated fear resulted in lower SCR scores than suppressed fear (z = -3.84 $p = .007$).

Happiness. Exaggerating SCR scores for the happiness stimuli were found to be statistically significantly lower than in suppressing happiness (z = -5.38; $p < .001$). Ekman happiness also resulted in lower SCR arousal compared to suppression (z = -3.29; $p =.006$) as well as verbal scores being lower than suppression (z = -2.97; $p = .016$). No significant differences were found between other conditions while experiencing happiness.

Sadness. Sadness in the verbal condition showed higher SCR than in Ekman condition (z = 5.72; $p < .001$) but lower SCR than suppressing (z = -5.83; $p < .001$) or exaggerating condition (z = -4.46; $p < .001$). Ekman sadness resulted in lower SCR than suppressed (z = -8.46; $p < .001$) or exaggerated sadness (z = -8.64; $p < .001$). Exaggerated sadness SCR was significantly lower than suppressed (z = -3.70; p =.001).

Surprise. No significant differences were found between surprise elicited SCRs in verbal and suppressing condition and between verbal and exaggeration conditions. SCR elicited by verbal surprise was higher than Ekman surprise (z = 5.48; $p < .001$), Ekman surprise SCR scores were lower than suppressed surprise (z = -5.15; $p < .001$) and exaggerated surprise (z = -2.69; p = *.04*). Exaggerated surprise elicited lower scores than suppressed surprise (z = -5.51; $p < .001$).

Pairwise interactions within conditions

Figure 7 below illustrates the pairwise comparisons between all factor levels (emotions) within four different conditions.

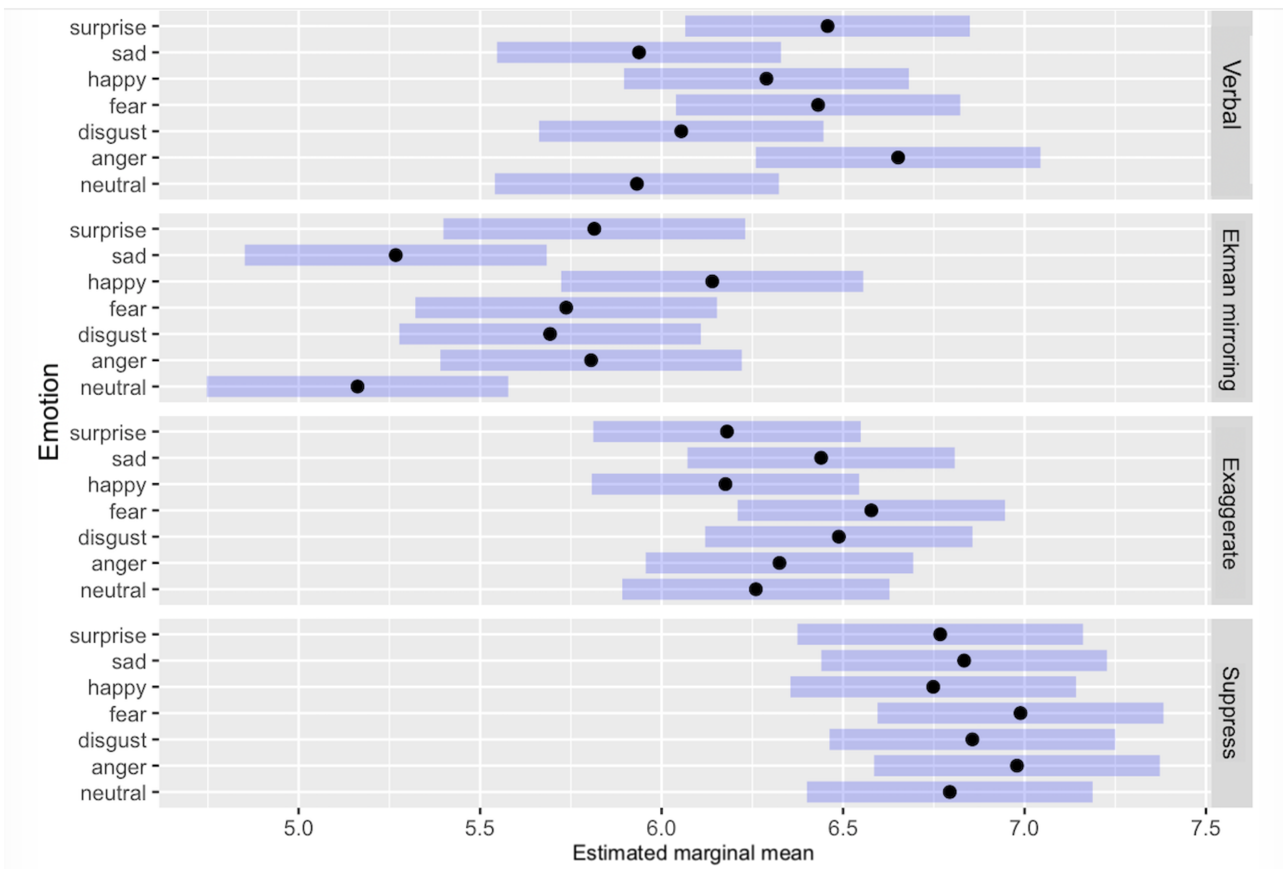


Figure 7. *Pairwise comparisons between estimated marginal means of seven factor levels (emotions) within four conditions. The dot (●) indicates the estimated marginal mean of square rooted SCR scores and the brackets a 95% confidence level interval.*

As can be seen in Figure 7, suppressing emotional reactions has the strongest effect on SCR within all seven emotions. Emotion specific arousal patterns are most differentiated in the Ekman mirroring condition.

Mirroring Ekman's faces

Within mirroring Ekman's faces condition, all emotions except sadness were statistically significantly different from neutral (p < .001). Significant differences were also found between anger and sadness (z = 4.88; p < .001), anger and happiness (z = -3.03; p = .04), disgust and happy (z= -4.04; p = .001), disgust and sad (z= 3.85; p = .02), fear and happiness (z= -3.64; p = .005), fear and sadness (z = 4.25; p < .001), happiness and sadness (z = 7.86; p < .001), happiness and surprise (z = 2.93; p = .05) and sadness and surprise (z = -4.94; p < .001).

Written words as verbal cues

Significant differences within verbal condition were found between the following emotions: neutral and anger (z = -6.50; p < .001), neutral and fear (z = -4.52; p < .001), neutral and happy (z = -3.22; p = 0.02), neutral and surprise (z = -4.75; p < .001), anger and disgust (z = 5.37; p < .001), anger and happy (z = 3.25; p = 0.02), anger and sadness (z = 6.44; p < .001), disgust and fear (z = -3.40; p = .01), disgust and surprise (z = -3.63; p = .005), fear and sadness (z = 4.47; p < .001), happiness and sadness (z = 3.16; p = .03), sadness and surprise (z= -4.69; p < .001).

Expression modulations to IAPS stimuli

No significant SCR differences were found comparing different emotions within the suppressing condition (p > 0.05). Significant differences within the exaggerate condition were found between fear and surprise (z = 4.63; p < .001), disgust and surprise (z = 3.60; p = .006), disgust and happiness (z = 3.65; p = .005), anger and fear (z = -2.59; p = .05) and neutral and fear (z = -3.72; p = .004). All differences between the emotions within every condition are presented in Tables 2a&b.

Table 2a

Post hoc tests pairwise comparisons between all factor levels emotions in verbal and Ekman conditions

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger		0.9476	0.9961	**0.0400**	**<.0001**	1.0000	**<.0001**
Disgust	**<.0001**		0.9997	**0.0010**	**0.0023**	0.9267	**<.0001**
Fear	0.4248	**0.0120**		**0.0052**	**0.0004**	0.9925	**<.0001**
Happy	**0.0199**	0.3487	0.8625		**<.0001**	0.0524	**<.0001**
Sad	**<.0001**	0.9414	**0.0002**	**0.0262**		**<.0001**	0.9635
Surprise	0.5853	**0.0053**	1.0000	0.7400	**0.0001**		**<.0001**
Neutral	**<.0001**	0.9261	**0.0001**	**0.0219**	1.0000	**<.0001**	

Note. Upper right table depicts the comparisons of emotions within the Ekman faces condition. Bottom left describes emotion differences in the verbal condition. **Statistically significant *p*-values are presented (≤ 0.05) in bold.**

Table 2b

Post hoc tests pairwise comparisons between all factor levels emotions in exaggeration and suppression conditions

	Anger	Disgust	Fear	Happy	Sad	Surprise	Neutral
Anger		0.4743	**0.0498**	0.5906	0.8330	0.6250	0.9885
Disgust	0.7791		0.9434	**0.0048**	0.9976	**0.0059**	0.1035
Fear	1.0000	0.7132		**0.0001**	0.6716	**0.0001**	**0.0037**
Happy	0.0978	0.8682	0.0740		**0.0334**	1.0000	0.9579
Sad	0.6081	1.0000	0.5334	0.9539		**0.0391**	0.3472
Surprise	0.1673	0.9449	0.1305	1.0000	0.9873		0.9675
Neutral	0.3121	0.9907	0.2548	0.9983	0.9992	0.9999	

Note. Upper right table depicts the comparisons of emotions within the exaggerating condition. Bottom left describes emotion differences in the suppressing condition. **Statistically significant *p*-values (≤ 0.05) presented in bold.**

While tables above show general SCR variation tendencies, examples of variations in skin conductance response of a single participant in suppressing condition within the response window (1-4 seconds) are demonstrated in a Ledalab plot (Figure 8) below. We can see increasing SCR activity during suppressing disgust emotion, higher but pretty stable SCR in reaction to anger and lower SCR indicators for neutral and surprise emotions.

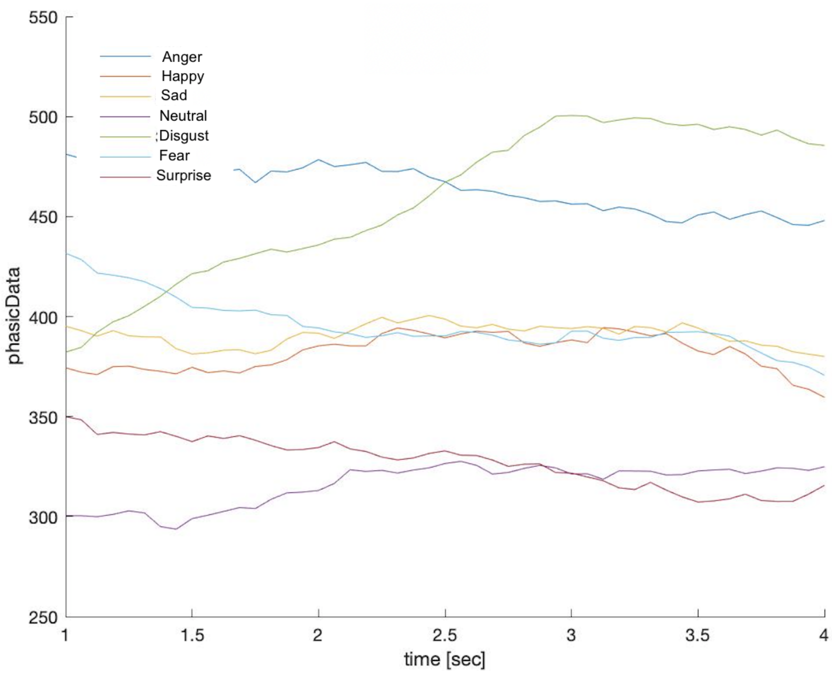


Figure 8. *Phasic activity in the suppression condition as measured in µS in the observed event-related interval (1-4 seconds).*

Self reported arousal ratings

Self report ratings to emotion intensity within suppression and exaggeration conditions were rated on Likert scale 0-100. A linear mixed-effects regression model as implemented in the *lme4* package (version 1.1.23; Bates et al., 2015) and *lmerTest* package (version 3.1.3, Kuznetsova et al. 2017) was fitted to the self-reported rating in exaggeration and suppression conditions. Pairwise factor combinations within fitted linear models were tested with the *emmeans* package (Lenth et al., 2018). The final model included self report ratings as the dependent variable and emotion (neutral as the reference level) as well as condition (exaggeration as the reference level) as fixed fixed effects. Random intercepts by subjects as a random effect in the model as well as an interaction between the emotion and condition were also included in the model. Full results of the final model are presented in supplementary material (Table 4).

The final model showed significantly lower intensity ratings in suppression than in exaggeration condition (β = -3.876, t = -2.01 p = .04). All emotions were rated significantly higher than the neutral emotion (fear: β =30.36, t = 11.52, p < .001, disgust: β = 43.38, t = 22.51, p < .001, fear: β = 35.60, t = 18.47, p < .001, happiness: β = 22.20, t = 11.52, p < .001, sadness: β = 38.96, t = 1.93, p < .001, surprise: β = 24.15, t = 12.53, p < .001). Finally, there was a significant interaction between the suppression condition and fear emotion (β = -6.36, t = -2.33, p = .02).

As a *post hoc* analysis, pairwise comparisons between emotions in both conditions were computed. Self report based emotion specific arousal pattern remained the same within both conditions, however pairwise comparisons of estimated marginal means of self report ratings revealed higher intensity ratings during the exaggeration task for all emotions as presented in Table 3.

Table 3

Self reported ratings means comparisons exaggerating vs suppressing condition

Emotion	**Estimate**	**SE**	*z*	***p***
Neutral	3.88	1.93	2.01	*
Anger	8.02	1.93	4.16	***
Disgust	8.02	1.93	4.15	***
Fear	10.24	1.93	5.31	***
Happy	8.43	1.93	4.37	***
Sad	7.57	1.93	3.93	***
Surprise	9.02	1.93	4.68	***

Note. * indicates p < .05; ** indicates p < .01; *** indicates p < .001. SE indicates standard error for the regression coefficient.

No significant correlation was found between self reported arousal and general SCR scores in two conditions taken together (r = 0.08; p = .003). When compared separately within condition, slight but statistically significant correlation was found in the exaggerating condition ($r = 0.1$; $p = .006$). Within emotion correlations remained relatively low, the most significant ones being fear ($r = 0.22$) and disgust ($r = 0.18$). No significant differences between SCR and self rated intensity were found in the suppression condition ($r = -0.04$; $p = .3$).

Discussion

The present study examined how skin conductance response reacts in response to various emotions in different stimulus domains and how facial expression focused response modulation affects arousal measured by SCR.

Emotion specific arousal patterns. It was concluded that the emotion specific arousal pattern was most detectable within Ekman mirroring task, although overall SCR scores remained low compared to the other three conditions. Ekman facial mirroring condition reflected more statistically significant differences between emotions than other conditions. SCR scores of sadness and neutral remained the lowest, reflecting a low arousal pattern. The highest SCRs were elicited in reaction to happiness, followed by surprise and anger which supports findings on arousal patterns from previous research (Bustamante et al., 2015; Russell, 1980). In contrast: the suppression condition, which showed the highest SCR scores overall, did not differentiate between arousal patterns on specific emotions. No significant SCR differences were found comparing different emotions within the suppression condition. It could be concluded that suppressing emotional reactions raises general autonomic arousal but lowers differences between emotion specific arousal patterns. Verbal condition, in which overall SCR scores were higher than in the Ekman condition, but slightly lower than in suppression/exaggeration, also revealed some statistically significant differences between emotions. Anger elicited the highest SCR scores within verbal condition, followed by surprise and fear. The exaggerating condition showed less but still a few significant differentiations within the arousal patterns. The highest SCR scores in the exaggeration condition were reported in response to fear, followed by disgust and sadness. The latter result is rather surprising, since sadness is generally considered a low arousal emotion. Moreover, exaggerated sadness elicited statistically significantly higher arousal than surprise and happiness. The latter two emotions are generally considered highly arousing and they did elicit higher SCR scores than sadness in all other conditions. Hence, modifying our emotional response raises general levels which affects emotion specific arousal differently. That conclusion rejects the first hypotheses of the current paper- higher arousal emotions do not always elicit higher skin conductance response in different experiment conditions when general arousal rises and emotion specific arousal pattern does not remain the same. It can be concluded that although emotions generally show different autonomic arousal patterns in terms of high and low arousal, emotional response modulation has a significant effect on the arousal pattern. Arousal measured by SCR itself does not affect all emotions in the same way.

Self reported ratings. Self report based emotion specific arousal patterns were somewhat consistent to SCR scores in suppression and exaggeration conditions. In contrast to SCR scores, all emotions received higher intensity ratings in the exaggeration condition compared to the suppression condition. Neutral emotion received the lowest intensity ratings, followed by happiness and surprise. Highest rated emotion appeared to be for disgust, followed by sadness, fear and then anger. In conclusion, self reported ratings do not necessarily align with arousal measured by SCR or to the circumplex model. However the overall emotion specific arousal pattern seems to be more response modulation resistant and more stable in different conditions. The relationships between self reported ratings and autonomic arousal require further research.

Response modulation. Suppressing emotional reactions had the strongest effect on arousal measured via SCR within all seven emotions. Exaggerating emotions resulted in the second highest skin conductance reaction rates within all emotion categories, supporting the second hypothesis that response modulation increases the phasic component of electrodermal activity and therefore raises arousal. These findings are consistent with previous research (Demaree et al., 2006; Gross 1998, 2002; Goldin, 2008) suggesting that response focused regulation strategies increase sympathetic activation and indicating that changes in facial musculature play an important role in emotional processes (Hubert & Jong-Meyer, 1990). Even neutral emotion showed highest SCR scores in suppressing out of all conditions, supporting the evidence that response modulation task itself affects sympathetic arousal. It's been previously suggested (Gross et al., 1998, 2000), that different forms of emotion regulation have different consequences, future research could compare emotion specific arousal patterns in various conditions, for example reappraisal.

Differences in facial and written verbal stimuli. The third hypothesis about skin conductance response being higher in response to facial stimuli (Ekman's faces) versus verbal cues was not confirmed. In fact, verbal cues elicited statistically significantly higher skin conductance rates in all emotions besides happiness, where the difference between the two conditions remained insignificant. Those results are similar to Bayer & Schacht (2014) results on electrocortical activity, according to which words did not receive lower arousal ratings than pictures or facial expressions in EPN (early posterior negativity) and LPC (late positive complex).

Experimental design specifics. In addition, linear mixed effect analysis revealed that the dependent variable (average level of skin conductance response as measured by μS) was impacted by the position a stimulus held in the sequence of trials and the number of repetitions. As suggested by Gatti et al. (2018), the effect of the triggering event on the skin conductance response might decrease after several presentations of emotional stimuli, as the participant could habituate to the emotional stimulation itself. In other words, by being emotionally stimulated repeatedly, a participant could grow accustomed to the emotional impact of the eliciting stimuli, therefore not being scared, moved, or aroused by a stimulus as it would be if the stimulus was presented at the beginning of the experiment. Habituation of the response when the same stimulus is repeated and dishabituation (when the repeated stimulus changes in some parameter) is also indicative that the system is correctly processing the environmental information (Mas-Herrero et al., 2018). Dindo (2007) has also proposed that the decline in electrodermal activity in trials might reflect emptying of the sweat gland ducts to a point at which sweat gland secretion.

In conclusion, SCR scores differentiated the four conditions presented in the current paper. It was confirmed that suppressing and exaggerating facial emotion expressions increase SCR scores the most and therefore reflect higher ANS activity. Emotion specific arousal patterns, can be better observed in conditions with lower SCR scores, emotions that would normally cause high arousal, may result in lower arousal than high intensity emotions when emotional expression is modulated. Current results also highlighted important contradictions between self reported and physiological arousal. This can be important from a psychophysiological, psychological and educational point of view and sets important groundwork for the future studies of emotional expression and regulation strategies.

Limitations and Future Directions

The aim of the current paper was to examine skin conductance response within different emotional conditions. There were a few limitations that should be taken into account regarding the present study and planning future research. First, no electrodermal activity was collected in absence of stimulation prior to the experiment onset, hence no electrodermal activity baseline was observed. Measuring baseline skin conductance for a few minutes before the start of the experiment would be helpful to detect whether some participants are likely to be hyper or hypo-responders independent of any effects of psychological manipulation. Secondly, repeated emotional stimulation seemed to cause habituation effects. For future experiments it may be worth considering fully randomizing the order conditions presented to the participant. Furthermore, reactions to facial expressions and written words were observed in mirroring and expressing condition, without any response modulation counterparts. To compare more specifics of SCR within different emotional conditions, and further investigate the effects of expression focused response modulations, it would be important to add suppression and exaggeration conditions to facial and verbal stimuli. It also might be worth considering adding a non regulated condition to future experiments for more accurate results. By including a “no regulation” condition as a control condition, we can compare each regulation strategy to whatever participants do when they are not told to regulate (Gross, 2002). It is also worth mentioning that the current experiment setup contained only one positive emotion. This unequal representation of only one positive as contrasted to five negative emotions is not unusual in empirical research but may bias the results. Lastly, there is always a possibility that IAPS pictures may not represent the same emotion for every participant when asked to express an emotion based on a picture with no added label (i.e., “sad”). Interpretation of the emotions a picture should elicit may thus be rather individual. Kalev (2021) carried out a pilot study on the same experiment, showing that when independent raters evaluated the facial expressions of those responding to IAPS, they did not always come to similar conclusions on the elicitation of the emotion intended by the IAPS (i.e., they did not necessarily rate the person reacting to an “angry” emotion as showing an angry facial expression).

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Supplementary Material

Table 1a

Linear mixed-effects model interactions using neutral verbal stimulus as reference level

Scaled residuals

Min	1Q	Median	3Q	Max
-4.29	-0.56	-0.11	0.38	5.57

Random effects

Groups	Name	Variance	SD
Participant id	Intercept	3.73	1.93
Residual		4.16	2.04

Fixed effect	Estimate	SE	*t*	*p*
Ekman anger	-7.64	1.56	-0.49	
Exaggerated anger	-6.55	1.40	-4.68	***
Suppressed anger	-5.35	1.40	-3.83	***
Ekman disgust	4.08	1.56	2.62	**
Exaggerated disgust	1.06	1.40	0.76	
Suppressed disgust	-6.00	1.40	-0.43	
Ekman fear	7.55	1.56	0.49	
Exaggerated fear	-1.81	1.40	-1.30	
Suppressed fear	-3.04	1.40	-2.18	*
Ekman happy	6.20	1.57	3.96	***
Exaggerated happy	-4.41	1.40	-3.15	**
Suppressed happy	-4.03	1.40	-2.88	**
Ekman sad	9.94	1.56	0.64	
Exaggerated sad	1.74	1.40	1.25	
Suppressed sad	3.37	1.40	0.24	
Ekman surprise	1.27	1.56	0.81	
Exaggerated surprise	-6.05	1.40	-4.33	***
Suppressed happy	-5.52	1.40	-3.95	***

Note. * indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$. SE indicates standard error for the regression coefficient.

Table 4

Linear mixed-effects model interactions using neutral stimulus in exaggerated condition as reference level

Scaled residuals

Min	**1Q**	**Median**	**3Q**	**Max**
-3.70	-0.68	-0.00	0.63	4.02

Random effects

Groups	**Name**	**Variance**	**SD**
Participant	Intercept	217.0	14.73
Residual		401.3	20.03

Fixed effects	**Estimate**	**SE**	***t***	***p***
Intercept	18.17	1.97	9.23	***
Suppression condition	-3.88	1.93	-2.01	*
Anger	30.36	1.93	15.75	***
Disgust	43.38	1.93	22.50	***
Fear	35.60	1.93	18.46	***
Happy	22.20	1.93	11.52	***
Sad	39.00	1.93	20.21	***
Surprise	24.15	1.93	12.53	***
Suppressed anger	-4.15	2.73	-1.52	
Suppressed disgust	-4.14	2.73	-1.52	
Suppressed fear	-6.36	2.73	-2.33	*
Suppressed happy	-4.55	2.73	-1.67	.
Suppressed sad	-3.70	2.73	-1.36	
Suppressed surprise	-5.15	2.73	-1.89	.

Note. **.** indicates $p < .1$; * indicates $p < .05$; ** indicates $p < .01$; *** indicates $p < .001$. SE indicates standard error for the regression coefficient.

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