THE ROLE OF POSITIVE FACIAL FEEDBACK IN THE STRESS RESPONSE

BY

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Abstract

This study investigated whether the old adage "grin and bear it" has proven value by testing how covert and overt manipulation of facial expression influences affective and physiological responses to stress. One hundred and sixty-nine healthy college students were recruited for a "multitasking study," which involved holding chopsticks in the mouth while simultaneously completing two stressful tasks. Participants were randomly assigned to one of the following conditions per the orientation of the chopsticks in their mouths: no smiling (control), Duchenne smiling, or non-Duchenne smiling. Awareness was also manipulated with one half of participants in each smiling condition specifically told to smile and the other half not (N=55 and 57, respectively). State affect changes were assessed at baseline and after each stress task using a short form of the Profile of Mood States, and change scores for positive and negative affect (average PA and NA during each task minus average baseline PA and NA) were used in an analysis of variance to test whether individuals experienced emotional changes concordant with their condition. Group differences in cardiovascular reactivity were examined using analysis of variance with change scores (average cardiovascular activity (heart rate, pulse, and blood pressure) during each task minus average cardiovascular activity at baseline). Repeated measures analysis of variance was employed with pulse and heart rate time points throughout each recovery period to examine group differences in cardiovascular recovery. In all analyses, the following variables were controlled for based on associations with the relevant cardiovascular DV: age; race; sex; body mass index (BMI); baseline perceived stress; sleep; smoking; alcohol use; exercise; condition adherence; perceived task difficulty; reported task facial muscle fatigue; and perceived task stress. Results indicated that non-aware participants in the smiling conditions (M = -0.32) reported less of a decrease in positive affect during a stressful task than individuals in the neutral group (M = -0.65), $F(1, 71) = 4.21$, $p < 0.05$, supporting the facial feedback hypothesis (i.e., smiling buffered the negative impact of stress). Generally, smiling had no consistent impact on the stress reactivity of participants as compared to non-smilers across cardiovascular outcomes and tasks. On the other hand, smiling showed widespread effects on cardiovascular recovery, with the smiling groups, regardless of awareness or type of smile, consistently returning closer to baseline levels of cardiovascular activity at the end of the recovery periods following both stress tasks. Practical implications of this relationship between facial feedback, affect, and the stress response are discussed.

The Role of Positive Facial Feedback in the Stress Response

For thousands of years, from the writings of Aristotle to the modern-day magazine articles and self-help books that flood bookstores across the globe, humanity has been captivated by the pursuit of happiness. Most recently in 1998, American Psychological Association president Martin Seligman challenged the field of psychology to more rigorously address this age-old question by making Positive Psychology the theme of his presidency (Seligman, 2002). Research on psychopathology had dominated the field since its origin, and Seligman's Positive Psychology movement ambitiously set out to balance the focus of psychological research on psychopathology and human well-being. In the past decade, scientists globally have responded with a wealth of research on what makes humanity thrive, and emotion researchers have particularly embraced this challenge. For example, Diener and Larsen (1993) found that most people define happiness as experiencing more positive than negative emotions. More specifically, positive emotion has been found to have several psychological and physical health benefits, particularly when employed during stressful situations (for reviews see Lyubomirsky, King & Diener, 2005; Pressman & Cohen, 2005).

Among the several theories that shed light on how emotion functions, one of the most controversial is the facial feedback hypothesis (FFH), which states that activation of facial muscles can influence a person's emotions (Tourangeau & Ellsworth, 1979). The FFH suggests that we not only smile because we are happy but that smiling can actually make us happier. Although many researchers agree that facial muscle manipulation can produce positive emotion, and positive emotion has been suggested to buffer the effects of stress, no published studies have tested whether facial muscle manipulation can directly protect against the negative effects of stress. In other words, does the old maxim "grin and bear it" have proven value? Can smiling itself be a protective factor in times of stress? It is necessary to examine the relationship between positive emotion, stress, and facial feedback in order to answer these questions.

Positive Emotion, Stress, and Health

Discussing emotion can become complex with the use of various related words, such as “mood” and “affect.” Throughout the literature, “emotion” generally refers to a momentary, short-lived feeling, whereas “mood” or “state affect” describe feelings lasting for a period of several minutes or days. “Affect” in general is a broader category that describes overall valence (positive or negative) of an emotion (Feldman Barrett & Russell, 1998; Watson & Tellegen, 1985). The terms “state” and “trait” are used to describe length of emotional experience, with “state” describing emotional experience at a particular moment and “trait” describing emotional experience on average. Throughout the literature discussed, these terms will all be used, depending on each author’s term choice.

Although the current study will conceptualize affect in terms of valence (positive versus negative) (Feldman-Barrett, 1998; Watson & Tellegen, 1985), many researchers suggest that affect is best described in terms of both valence (positive or negative) and arousal (high or low activation), which is referred to as the circumplex model of affect (Larsen & Diener, 1992; Russell, 1980). For example, both “calm” and “excited” would be positive in terms of valence, but “calm” would be considered low activation and “excited” high activation. Although this differentiation is outside the scope of the current study, it is important to note differences between a one dimensional model focusing only on valence and the circumplex model in order to understand the range of emotions that are included the two dimensions of positive and negative affect discussed in the current study.

Numerous studies have highlighted the psychological and physical health benefits of positive emotion, ranging from greater resiliency during traumatic or stressful times to stronger immune functioning (for reviews see Lyubomirsky et al., 2005; Pressman & Cohen, 2005). One study even linked positive emotion to longevity, reporting that nuns who recorded more positive emotion words in their autobiographies lived longer than those who recorded fewer positive emotion words (Danner, Snowdon, & Friesen, 2001). Fredrickson's (2001) well-accepted broaden-and-build theory states that one pathway for these benefits is via the ability of positive emotions to broaden peoples' thought processes, allowing them to build beneficial resources to call upon during stressful times. For example, positive emotions help us form healthy friendships and learn skills or hobbies that could be helpful and serve as protective factors when facing adverse situations. Research has supported this theory, revealing that individuals who experience frequent positive emotion not only are more likely to set and reach goals while experiencing positive emotion but have more resources built up during times of past positive emotional experiences to utilize when needed (Lyubomirsky et al., 2005).

In general, people who experience frequent positive emotion are also more likely to graduate from college, secure a steady job and be satisfied with that job, earn more money, and have a greater social network (Lyubomirsky et al., 2005). Positive emotion has been similarly linked to a number of specific physical and mental health outcomes, including fewer rates of psychological disorders, lower presence of stress hormones, fewer visits to the hospital, and lower sensitivity to and higher tolerance of pain (Lyubomirsky et al., 2005; Pressman & Cohen, 2005).

Most of these findings are the result of correlational research, making it impossible to conclude that positive emotion is the cause of these outcomes. There have, however, been a handful of experiments helping us understand the causal effect of positive emotion on health outcomes, particularly in the context of stress. For example, in a study by Fredrickson and Levenson (1998), participants who received a positive mood induction after a stressful or negative emotion inducing video clip returned to their resting levels of cardiovascular activity more rapidly than their non-positive counterparts (using a combined measure of heart rate, pulse transmission to the ear, pulse transmission to the finger, and finger pulse amplitude). Particularly relevant to the project at hand, Fredrickson & Levenson also noted whether or not individuals spontaneously smiled at any point during the stress experience. Those who did, irrespective of condition, returned to their baseline cardiovascular state sooner, suggesting that facial activation may be particularly helpful in speeding stress recovery by reducing the negative aftereffects of stress. However, because smiling was not randomly assigned, we can not infer whether this is due to the facial expression itself or due to baseline differences in affective style. Finally, in a series of three studies (two examining daily self-reported stressors and positive emotion in the general population and one examining daily self-reported stressors and positive emotion in a sample of bereaved widows) using multilevel modeling, Ong, Bergman, Bisconti, & Wallace (2006) found the experience of daily positive emotion to be beneficial in reported ability to manage daily stressors among the general population as well as those coping with bereavement.

Taking these findings and other current literature into consideration, Pressman and Cohen (2005) have suggested two primary pathways by which positive emotion influences health: directly or by buffering the effects of stress. The “main (direct) effect” model states that long-lasting state or, more commonly, enduring trait positive affect has the biggest influence on health outcomes because it is directly associated with the following: 1) better health practices (e.g., exercising more frequently and improving sleep quality), 2) generally decreased sympathetic nervous system activity and increased parasympathetic nervous system activity, which reduces the cardiovascular response (although there is some evidence that extremely activating positive affect can have the opposite effect), 3) changes in levels of hormones released by the hypothalamic-pituitary-adrenal (HPA) axis (i.e. reducing the production of cortisol, which is associated with the stress response and inflammatory diseases, and increasing the production of oxytocin, which has been found to decrease cortisol levels, and growth hormone, which is essential for healthy development, 4) increased levels of endogenous opioids, which can decrease endocrine activity, alter immune functioning and reduce the overall experience of pain, 5) improved immune functioning, possibly by affecting white blood cell circulation and increasing certain antibodies, and 6) more social relationships and increased social activity, which has been associated with better overall health.

Alternatively, the "stress-buffering" model states that positive affect primarily influences health by reducing the harmful effects of the stress response. There are several ways in which positive affect could influence the stress response, including the following: 1) individuals who experience high levels of positive affect may encounter less stress in general, either because they are less likely to experience stressful situations or because they have more resources built up to handle stressful situations more adequately than most, which is consistent with Fredrickson's (1998) "broaden and build" theory, and 2) experiencing positive affect prior to, during, or following a stressful event can lead to a faster return to normal cardiovascular activity levels.

This common experience of increased cardiovascular activity (e.g. heart rate and blood pressure) due to a stressful event is formally called cardiovascular stress reactivity and is defined as "an individual's propensity to experience cardiovascular reactions of greater or lesser magnitude, in relation to those of other persons, when encountering behavioral stimuli experienced as engaging, challenging, or aversive" (Manuck, 1994). Stress reactivity is measured by monitoring elevations in blood pressure and heart rate before, during, and after a stimulus and subtracting the mean scores during the presentation of the stimulus from the mean scores collected at baseline (Goyal, Shimbo, Mostofsky, & Gerin, 2008). It has been shown to be a predictor of health problems, such as hypertension, atherosclerosis, and coronary heart disease (for reviews, see Goyal, et al., 2008; Treiber, Kamarck, Schneiderman, Sheffield, Kapuku, & Taylor, 2003). In addition, research has shown that people who experience high levels of negative affect experience more stress reactivity (Feldman, Cohen, Lepore, Matthews, Kamarck, & Marsland, 1999; O'Brien, Terry & Jimmieson, 2008). Furthermore, stress reactivity predicts depressive symptoms better than overall stress level, and high levels of reactivity to small stressors throughout the day can be more detrimental to mood than overall stress level in general (Felsten, 2002, 2004). Lerner, Dahl, Hariri and Taylor (2007) suggested that there is a direct relationship between facial expression and stress reactivity as well, with participants who expressed fear having high reactivity but participants who expressed indignation having low reactivity to an identical stress task.

In addition to stress reactivity, it is also important to consider stress recovery, which is assessed by examining the period of time immediately following a stressor to evaluate how long the physiological and psychological effects of the stressor endure (Linden, Earle, Gerin, & Christenfeld, 1997). Recovery has been formally defined as a return to baseline after a stressor has ended (Haynes, Gannon, Orimoto, O'Brien, & Brandt, 1991); however, it is also frequently assessed as a statistical model of the slope of cardiovascular activity following the termination of a stressor, such that group differences can be observed by examining which groups more rapidly approach baseline levels of cardiovascular activity within the designated recovery period.

It is essential to examine cardiovascular stress recovery in addition to stress reactivity as an outcome measure because both describe distinct aspects of the stress response and provide unique information as to how various stimuli affect the stress response. For example, it is widely known that being in good physical shape is associated with increased ability to manage stressful situations; however, physically fit individuals actually experience similar cardiovascular stress reactivity to psychological stressors as individuals who are not physically fit. The difference lies in the ability of physically fit individuals to recover faster from psychological stressors (e.g. Jamieson & Lavoie, 1987). Similarly, in a study examining the effects of forgiveness on the stress response, Whited, Wheat, and Larkin (2010) found that although no differences were seen between groups in terms of reactivity, participants who were able to forgive verbal harassment during a serial subtraction task displayed significantly faster recovery from the task. Differences in recovery have also been shown to be salient outcomes for clinical populations, particularly individuals with eating disorders (Messerli-Burgy, Engesser, Lemmenmeier, Steptoe, & Laederach-Hofmann, 2010), and most pertinent to the current study, Papousek, Nauschnegg, Paechter, Lackner, Goswami, & Schulter (2010) found that trait positive affect, independent of negative affect, was related to better "more complete" recovery from an academic stressor, which lends support to Levenson's (1988) suggestion that the purpose of positive emotions "might be to function as efficient 'undoers' of states of ANS [autonomic nervous system] arousal produced by certain negative emotions" (p. 25). However, Papousek et al. (2010) also reported that state affect immediately prior to the stressful event was related to poor recovery from the academic stressor, which highlights the importance of examining state and trait affect separately in order to determine the specific relationship between affect and recovery.

Given these findings and the numerous health benefits associated with PA, there is growing interest in determining whether affect can be manipulated in meaningful ways. While positive psychology is focused on complex interventions to increase happiness (for a review, see Sin & Lyubomirsky, 2009), it is also possible that something as simple as a facial expression may also have benefit for positive feelings. Additionally, the intention of some positive psychology interventions is obvious, which makes it more likely that demand characteristics might lead individuals to become resilient to the their effects. For example, the "gratitude" exercise simply asks individuals to make a list of things they are grateful for and the "Best Possible Self (BPS)" exercise asks individuals to do exactly as the name suggests: visualize themselves at their "best" (Sheldon & Lyubomirsky, 2006). Thus, smiling may be a covert way of manipulating emotion without the effects of psychological resilience or demand characteristics interfering.

Facial Feedback Hypothesis

Since Darwin's hypothesis over a century ago that specific facial expressions are instinctive and universal (Darwin, 1872), researchers have built a vast literature not only supporting Darwin's hypothesis but also building on it. Particularly, research in several countries has investigated the relationship between facial expression and emotion. Although instinctively there is a relationship between facial expression and emotion, the causal direction has been somewhat controversial in the literature. William James (1890) first suggested that physical changes in the muscles and circulatory system of the body directly impact the experience of emotions, and shortly after, Tomkins (1962) hypothesized that the muscles of the face are specifically involved in the creation of an emotional experience. This notion that facial muscle activation could directly influence a person's emotions became known as the facial feedback hypothesis (FFH) (Tourangeau & Ellsworth, 1979).

Because of initial hypotheses about the relationship between facial expression and emotion by both Darwin (1872/1965), who claimed that facial expression or suppression could influence the intensity of an emotional experience, and James (1890/1950), who argued that physical muscular and circulatory changes in the body could be the cause of an emotional experience, two specific paradigms of the FFH have been formulated and tested. First, research has examined whether expressing or suppressing facial expression can influence the intensity of an emotional experience, with several studies asking participants to amplify or suppress their emotional reaction to stimuli in the form of images, video clips, or olfactory stimuli (e.g., Colby, Lanzetta & Kleck, 1977; Kraut, 1982; McCanne & Anderson, 1987**;** Zuckerman, Klorman, Larrance, & Spiegel, 1981). Kraut (1982) had participants smell pleasant and unpleasant odors and make either a pleasant or disgusted facial reaction in response to the odor, even if the response was not natural. Results indicated that regardless of natural tendencies, the participants' evaluations of the odor matched their facial reactions.

Second, research has examined whether specific facial muscle configurations can produce the emotional experiences associated with them without any other stimulation involved, with several studies instructing participants to activate particular muscle groups without any emotionally eliciting stimulus to see how muscle activation alone affects the experience of emotions (e.g., Duclos et al., 1989; Hess et al., 1992; Laird, 1974; Rutledge and Hupka, 1985; Soussignan, 2002; Strack, Martin, & Stepper, 1988; Tourangeau and Ellsworth; 1979). Strack et al. (1988) produced one of the most classic studies testing this part of the FFH. The experimenters asked each participant to place a pencil in her or his mouth in different ways that activated the facial muscles involved in smiling and employed a cover story where participants believed they were a part of an experiment testing the ability to use one's mouth for certain tasks that would not normally be associated with the mouth, as physically impaired individuals would have to do to compensate for their impairment. Participants who had engaged the muscles involved in smiling through this covert task rated cartoons as funnier than participants in other conditions, which showed support for the FFH (Strack et al., 1988).

Instead of employing a cover story, other researchers have used a "directed facial task" to test the FFH that employed the Facial Action Coding System (FACS, Ekman & Friesen, 1978), which is an anatomical coding system that accounts for every muscle in the human face. Research using FACS has been able to specify and code exactly which facial muscles were activated when particular emotions were expressed (Ekman, Levenson & Friesen, 1983). For example, there has long been a distinction between a "real" and "fake" smile based on activation of the orbicularis oculi muscle surrounding the eye, and FACS coding has been able to assist research teams in detecting this small but relevant difference. A forced or fake smile, often referred to as a "non-Duchenne" smile, will engage the zygomaticus major muscles around the mouth, but only a real or "Duchenne" smile, named after its founder, will engage both the zygomaticus major and orbicularis oculi muscles (Duchenne, 1862/1990; Ekman & Friesen, 1982). In a study by Ekman, Davidson, and Friesen (1990), Duchenne smiling was seen more frequently when viewing pleasant films and was associated with activity in the left frontal lobe and the anterior temporal lobe, both of which have been associated with positive emotion (e.g., Abel & Hester, 2002; Davidson, 1984, 1992; Davidson & Tomarken, 1989; Kinsborne & Bemporad, 1984; Schwartz, Ahern, & Brown, 1979; Silberman & Weingartner, 1986; Tucker &

Frederick, 1989). Also, according to Tomarken, Davidson, Wheeler, and Doss (1992), individuals who experience more activity in the left mid-frontal and anterior temporal areas of the brain report experiencing more positive than negative emotions, and those who experience more activity in the right frontal lobe report the opposite.

Fox and Davidson (1988) similarly found that ten month old infants displayed Duchenne smiles when they saw their mothers' faces rather than strangers' faces and that the smiles were again associated with activity in the left frontal lobe. Furthermore, according to Abel and Hester (2002), research has shown that individuals without psychological disorders experience more Duchenne smiling than individuals with depression or schizophrenia, and more Duchenne smiling occurs when depressed individuals have been discharged than when they were first admitted to a treatment facility (Berenbaum & Nisenson, 1997; Krause, Steimer, Sanger-Alt, & Wanger, 1989; Matsumoto, 1987). Most recently, Harker and Keltner (2001) found that women who displayed a Duchenne smile in their yearbook pictures at age 21 were in better health physically and psychologically and reported being happier with their lives than other women from the same yearbook at ages 27, 43, and 52. Most important for the current study, however, is Ekman and Davidson's (1993) finding that voluntarily producing a Duchenne smile activated the same brain regions responsible for positive emotion as an involuntary Duchenne smile stimulated by an outside source. This lends increased support to the FFH and suggests that the emotions associated with facial muscle activation may be remarkably similar when elicited voluntarily and involuntarily.

Although they were the first to coin the term "Facial Feedback Hypothesis" for this phenomenon, Tourangeau and Ellsworth (1979) ironically found no significant evidence for it. However, since its formal label was introduced, numerous published studies have produced strong evidence in support of both paradigms of the FFH, with studies ranging from those asking participants to exaggerate a particular facial expression to studies asking participants to activate particular facial muscles or even paralyze certain muscles through the use of botulinum toxin (BOTOX) to determine effects on affect (e.g., Duclos, Laird, Schneider, Sexter, Stern & Van Lighten, 1989; Duclos & Laird, 2001; Flack, Laird, & Cavallaro, 1999; Havas, Glenberg, Gutowski, Lucarelli & Davidson, 2010; Hess, Kappas, McHugo, Lanzetta & Kleck, 1992; Ian Davis, Senghas, Brandt, & Ochsner, 2010; Kleinke & Walton, 1982; Kraut, 1982; Lanzetta, Cartwright-Smith, & Kleck, 1976; Lanzetta, Biernat, & Kleck, 1982; Larsen, Kasimatis, & Frey, 1992; Levenson, Ekman & Friesen, 1990; Levenson, Ekman, Heider, & Friesen, 1992; Rutledge & Hupka, 1985; Soussignan, 2002; Strack, Martin, & Stepper, 1988; Strack, & Neumann, 2000; Zuckerman, Klorman, Larrance, & Spiegel, 1981), while Tourangeau and Ellsworth's (1979) study remains among the minority of published studies to find no significant evidence for the FFH.

Current Study

The facial feedback hypothesis states that activation of facial muscles can influence a person's emotions. Activating the muscles involved in smiling in particular has been shown to increase appraisal and report of positive affect, and we hypothesized that an increase in self-reported positive affect would buffer the harmful effects of stress. This likely occurs by activating certain brain areas, although this is outside the scope of the current work. In general, for most people, the experience of positive affect leads to smiling, and this may have a stress-buffering impact. However, this study was concerned with whether facial feedback can cause an increase in positive affect, and whether facial feedback has a stress buffering impact. Although previous literature has used the terms "emotion," "mood," and "affect in interchangeable ways, the current study used “state affect,” to describe how participants felt throughout different points of the study.

This study, therefore, sought to better understand the facial feedback hypothesis and the extent it is involved in altering the stress response. Additionally, we explored what effect cognitive awareness of smiling had on the stress response by testing whether covert (unaware of smiling) and/or voluntary (aware of smiling) manipulation of facial muscles would reduce stress reactivity and speed stress recovery. Although previous studies with individuals working in customer service positions have shown that purposely “faking” facial expression and emotion leads to higher burnout rates and employee error (e.g., Brotheridge & Grandey, 2002; Goldberg & Grandey, 2007), no previous published studies have examined whether cognitive awareness of smiling differs from pure muscle activation without awareness of smiling. Thus, the current study primarily examined: (1) whether covert manipulation of facial muscles involved in smiling has an effect on state affect, providing evidence for or against the facial feedback hypothesis, (2) whether voluntary manipulation of facial muscles involved in smiling has an effect on state affect, and (3) whether facial feedback buffers the physiological stress response. Given that the published literature on smiling has previously suggested an association between spontaneous smiling and faster cardiovascular stress recovery (Fredrickson & Levenson, 1998), we anticipate this finding to be replicated in the current study. Finally, the following variables have been associated with cardiovascular outcomes in previous literature and were considered as covariates in the current study: age; race; sex; body mass index (BMI); baseline perceived stress; sleep; smoking; alcohol use; and exercise (Goyal et al., 2008). Furthermore, adherence to each facial muscle manipulation per condition was controlled for as well as the following variables that could have affected task completion: perceived task difficulty; reported task facial muscle fatigue; and perceived task stress.

Method

Participants

A total of 169 participants approximately ages 18-25 were recruited via the University of Kansas (KU) psychology department SONA system and randomly assigned to one of the experimental conditions or the control condition. The sample was 66% female and 34% male, and race representation was 79% Caucasian, 4% African American, 11% Asian or Pacific Islander, 5% Hispanic, and 1% of other races not listed. Only fluent English speakers were eligible for participation, and participants were screened for psychological disorders (e.g., Major Depressive Disorder, Generalized Anxiety Disorder, etc.) that would have interfered with state affect assessment as well as cardiovascular disorders, facial muscular disorders or connective tissue disorders that would have placed them at increased risk during the study. Participants were compensated with three credits towards their research requirement for Introduction to Psychology.

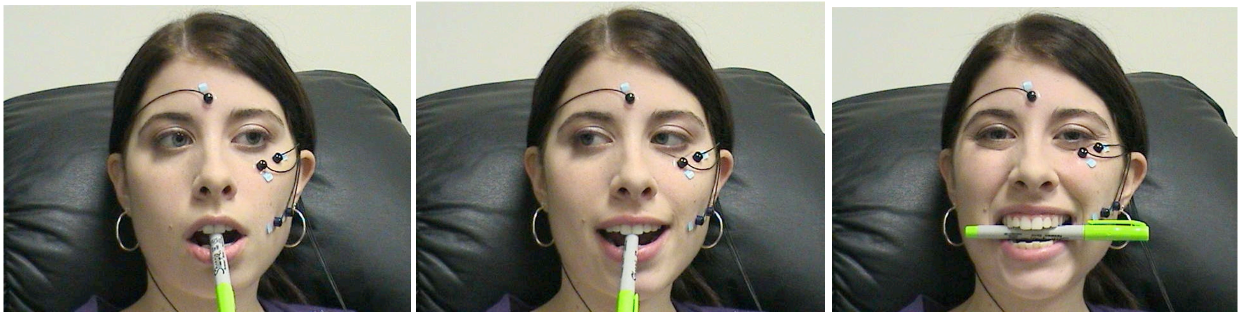
Design and Procedure

Participants completed a screening questionnaire, and those eligible completed baseline measures assessing affect, personality traits, and general demographic and health information. They were then assigned to a control group with no facial muscle activation, or one of the following experimental groups (See Figure 1): a covertly (not aware of smiling) manipulated Duchenne smiling group (activating the zygomaticus major muscle in the cheek and orbicularis oculi muscle in the eye area), a covertly (not aware of smiling) manipulated non-Duchenne smiling group (activating only the zygomaticus major muscle in the cheek), a voluntarily (aware of smiling) manipulated Duchenne smiling group, and a voluntarily (aware of smiling) manipulated non-Duchenne smiling group. The smiling groups were asked to hold a pair of chopsticks in their mouths with their teeth by mimicking the holding pattern of a research assistant (See Figure 1). Research assistants were trained using the Facial Action Coding System (Ekman & Friesen, 1978) to ensure that participants were activating the proper facial muscles of the experimental groups they were assigned to.

Given our interest in the effect of facial muscle activation on emotion without the interference of cognitive evaluation of facial expressions for two of our conditions, it was essential that subjects did not suspect that we were trying to make them feel certain emotions. Knowing that the study was about facial expression and specifically, the facial feedback hypothesis would have greatly interfered with our ability to interpret the findings. We were interested in whether facial change on its own would result in our proposed stress-buffering outcomes without the knowledge that these facial muscle changes are related to certain emotions. Thus, all participants were told a cover story that the purpose of the study was to examine how multitasking affects different kinds of task performance and were asked to perform a chopstick manipulation task using their mouths while simultaneously performing two different kinds of tasks. For the two voluntary (aware) smiling conditions, participants were additionally instructed to smile after hearing the cover story. For the two covert (unaware) smiling conditions, only the cover story was given to ensure that they were not focused on their facial expression throughout the study and therefore did not realize that they were expressing smiles (for a list of the condition instructions see Appendix E). Next, participants were led to a room where they were hooked up to an electrocardiograph (ECG) and a research assistant attached a blood pressure cuff to their dominant arm. Throughout the time that the participants were attached to electrodes, non-invasive, continuous measures of heart rate and blood pressure were taken.

After completing baseline questionnaires, participants rested quietly for ten minutes then completed a brief state affect questionnaire. Participants were then exposed to a star-tracing stress task asking them to place their non-dominant hand inside a metal box where they had to trace a star as many times as they could in two minutes while only being able to see a mirror image of the star. If participants went outside the lines of the star, a tone sounded, and research assistants stressed the importance of being as accurate as possible while stressing speed. A prize (a candy bar) was promised to the participant if he or she could trace the star at least eight times in two minutes with fewer than 25 mistakes, which was extremely difficult to accomplish. This offered an incentive to ensure motivation and good performance on the task. A measure of state affect was taken immediately after this stress task as well as questions about how stressful and difficult the task was for the participant and how tired his or her facial muscles were. A five-minute rest period followed the task. Next, participants were exposed to a second stress task where they had to hold their non-dominant hand in a bucket of ice water at two to three degrees Celsius for one minute. A measure of state affect was taken immediately after the stress task as well as questions about how stressful and difficult the task was for the participant and how tired his or her facial muscles were. A five-minute rest period followed the task. Finally, participants were asked what they thought the true purpose of the study was to ensure that our cover story was effective. They were then debriefed regarding the true study goals and granted credit. See Appendix E for complete instructions given to participants throughout the study.

Figure 1: Face Conditions (L-R) Neutral, Non-Duchenne smile, Duchenne smile



Materials

Positive and negative affect. Trait positive affect and negative affect were measured at baseline using a 54-item emotional traits questionnaire developed by the research team utilizing elements from McNair, Lorr, & Droppleman's (1971) Profile of Mood States (POMS), Watson, Clark, & Tellegen's (1988) Positive and Negative Affect Scale (PANAS), and Russell's (1980) circumplex model of affect. The scale presented several positive and negative trait items and ranged from 0 to 5 for each item, with 0 indicating that the item was very slightly/not at all how the participant felt on average and 5 indicating the item was very much how the participant felt on average. State positive affect and negative affect was measured at baseline and after each stress task by using a brief 19-item form of the Profile of Mood States (POMS) (Usala & Hertzog, 1989). The scale ranged from 0 to 4 for each item, with 0 indicating that the item was not at all accurate in describing how the participant felt at that moment, and 4 indicating that the item was extremely accurate in describing how the participant felt. Negative affect was measured based on two categories: anxiety (including jittery, nervous, and intense) and depression (including unhappy and sad). Intense is frequently conceptualized as a neutral high activation item; however, based on a factor analysis using varimax rotation, intense emerged as being part of the neutral and high arousal NA items, and upon examination of inter-item correlations, it was most strongly correlated with the item “JITTERY” (a high activation NA item) and was therefore included as part of the high arousal “anxiety” NA score. Positive affect was measured using three categories: vigor (including active, lively, and enthusiastic), well being (including happy and cheerful), and calm (including calm and relaxed).

Stress. The Perceived Stress Scale (PSS-10) was used at baseline to measure overall stress over the course of the past month (Cohen, Kamarck, & Mermelstein, 1983). The 10-item scale ranged from 0 to 4, with 0 indicating that the item had never occurred in the past month and 4 indicating that the item had occurred very often in the past month. To measure stress reactivity, blood pressure was collected continuously throughout the study using a standard blood pressure cuff on the participant’s dominant arm. Heart rate was also measured continuously throughout the study using an electrocardiograph (ECG), with seven electrodes placed on each participant’s core. Total stress reactivity scores were calculated by subtracting the mean blood pressure, pulse, and heart rate scores during the stress tasks from the mean blood pressure, pulse, and heart rate scores collected at baseline. We also assessed self-reported stress throughout the study with a repeated questionnaire that asked participants to rate how stressful they found the study’s tasks to be on a scale from 1 (not stressful at all) to 10 (extremely stressful).

Health practices. In order to gather information on sleep, a modified version of the Pittsburgh Sleep Quality Index (PSQI; Buysse, Reynolds, Monk, Berman, & Kupfer, 1989) was used. Sleep duration, time in bed spent sleeping, sleep quality, and napping behavior over the past month were collected. Information related to smoking, alcohol and illicit drug use, and general level of physical activity was also collected as part of the baseline questionnaire packet, as these have been associated with cardiovascular reactivity in previous literature (Goyal et al., 2008). These were used as possible control variables for the cardiovascular measurements given their known associations with health and heart outcomes.

Facial muscle activation. To ensure that the correct muscles were being activated for each experimental condition, participants were videotaped throughout the study, and videos were coded for adherence by two separate research assistants trained with the Facial Action Coding System (Ekman & Friesen, 1978) to recognize zygomaticus major and obicularis oculi activity in the face. The average of the two assistants' scores for each video was used to control for adherence throughout all analyses.

Cardiovascular Recording Apparatus. Blood pressure, mean arterial pressure, and pulse rate were recorded non-invasively every 90 seconds throughout the study using a blood pressure cuff and DINAMAP ProCare Auscultatory 400 Vital Signs Monitor (GE Medical Systems, Milwaukee, WI). Heart rate was measured continuously throughout the study using electrocardiography (ECG). ECG (and cardiovascular impedance data not reported in the current project) was obtained from six electrodes placed on the upper and lower sternum, the right clavicle, left lower ribcage, and right lower ribcage (ground lead) on the anterior side of the body, and on the cervical and thoracic regions on the posterior side of the body using a MindWare BioNex ECG amplifier. Data acquisition and recording of ECG was carried out using a MindWare BioLab 2.4 acquisition system, with a sampling frequency of 1000 Hz and a 60 Hz notch filter to reduce noise in the data. Average heart rate per minute was calculated for analyses using MindWare Heart Rate Variability (HRV) analysis software 3.0.9 (MindWare Technologies, Ltd., Gahanna, OH).

Statistical Approach

To analyze state affect changes and stress reactivity from baseline to each stress task, univariate analysis of covariance was used. State affect change was calculated by subtracting average reported levels of state PA and NA at baseline from average reported levels of state PA and NA during each stress task. Likewise, stress reactivity was calculated by subtracting average levels of cardiovascular activity (pulse, heart rate, and blood pressure) at baseline from average levels of cardiovascular activity throughout each stress task. Repeated measures analysis of variance was utilized to examine cardiovascular activity (pulse, heart rate, and blood pressure) throughout each recovery period time point; pulse and blood pressure were analyzed using measures collected every 90 seconds throughout each five-minute recovery period, and heart rate was analyzed by calculating average heart rate per minute throughout each recovery period. Heart rate is typically defined as the number of heart beats per specified unit of time, generally beats per minute (bpm) and pulse defined as the tangible palpation of a heartbeat through an artery (Merriam-Webster's Medical Dictionary, 2007). Because heart rate and pulse are so closely related, only results for pulse will be presented. However, because heart rate was a more sensitive measure than pulse because more data points were collected for heart rate than pulse, any significant results found with heart rate but not with pulse will also be presented.

For all analyses, the following group pairings were examined for differences: 1) Neutral vs. all smile groups; 2) Neutral vs. Duchenne smile groups; 3) Neutral vs. non-Duchenne smile groups; 4) Neutral vs. non-aware smile groups; 5) Neutral vs. aware smile groups; 6) Duchenne vs. non-Duchenne smile groups; 7) Aware vs. non-aware smile groups; 8) Neutral vs. Duchenne vs. non-Duchenne smile groups; and 9) Neutral vs. aware vs. non-aware smile groups.

In addition, the following variables have been previously shown to affect measures of the stress response: health behaviors (i.e. sleep, smoking, alcohol consumption, and exercise activity), age, race, sex, and general stress levels (Goyal et al., 2008). Thus, univariate analysis of variance and bivariate correlations were calculated to determine which variables to control for based on group differences and associations with the relevant cardiovascular DV.

Results

Statistical Procedure

Univariate ANOVA tests confirmed that there were no significant differences between groups at baseline in terms of age, $F(4, 164) = 0.38, p > 0.05$; sex, $F(4, 164) = 2.02, p > 0.05$; race $F(4, 164) = 0.45, p > 0.05$; or baseline negative affect $F(4, 160) = 1.18, p > 0.05$. No significant differences were found between groups in terms of baseline positive affect, with the exception of the neutral and non-aware smile groups, with the neutral group ($M = 2.16$) displaying slightly higher levels of PA at baseline than the non-aware smile groups ($M = 1.62$), $F(1, 84) = 10.69, p < 0.05$. In order to control for this baseline difference, change scores for both positive and negative affect were utilized rather than raw scores throughout all analyses. In addition, the following variables were controlled for based on associations with the relevant cardiovascular DV throughout all analyses: age; race; sex; body mass index (BMI); baseline perceived stress; sleep; smoking; alcohol use; exercise; condition adherence; perceived task difficulty; reported task facial muscle fatigue; and perceived task stress.

Affect Change throughout Stress Tasks

Positive and negative affect (PA and NA) change was analyzed using overall state affect change scores, calculated by subtracting each participant's average baseline positive and negative state affect scores on the POMS from their average positive and negative state affect scores throughout each stress task. Results for both PA and NA change revealed support for the facial feedback hypothesis. Specifically, following the cold pressor task, the non-aware smiling groups (*M* = -0.32) showed less of a decrease in PA from baseline than the control group (*M* = -0.65), *F*(1, 71) = 4.21, $p < 0.05$, in response to cold stress; the smiling groups showed less of a decrease in PA from baseline (*M* = -0.36) than the control group (*M* = -0.58), *F*(1, 115) = 2.56, p = 0.11; the Duchenne groups showed less of a decrease in PA from baseline (*M* = -0.36) than the control group (*M* = -0.60), *F*(1, 75) =2 .47, *p* = 0.12; and the non-aware smiling groups (*M*= -0.17) showed a decrease in NA from baseline following the cold pressor task, while the control group showed an increase (*M* = 0.07) *F*(1, 73) = 2.78, *p* = 0.10). (See Appendix B for graphs depicting these differences).

Cardiovascular Stress Response

Reactivity. Stress reactivity was calculated by subtracting mean scores of blood pressure, pulse, and heart rate throughout the ten-minute baseline period from mean scores of blood pressure, pulse, and heart rate throughout each of the stress tasks. Contrary to hypothesized results, there were generally no associations between facial condition and reactivity. After examining group differences between each of the nine planned group comparisons, only one significant difference was found, which may be spurious. The single finding was in the opposite hypothesized direction, with Duchenne smilers showing marginally *greater* mean diastolic blood pressure (DBP) reactivity than non-Duchenne smilers (Duchenne *M* = 10.74, Non-Duchenne *M* = 8.16) and marginally more mean heart rate (HR) reactivity (Duchenne *M* = 6.63, Non-Duchenne *M* = 3.98) during the Star Tracer Task, *F*(1, 94) = 3.09, *p* = 0.08; *F*(1, 68) = 2.89, *p* = 0.09, respectively. Similarly, Duchenne smilers showed more mean HR reactivity (*M* = 5.81) than the control group (*M* = 2.76) during the Cold Pressor Task, *F*(1, 53) = 2.93, *p* = 0.09). (See Appendix C for graphs depicting these differences).

Recovery. Each five-minute recovery period following the two stress tasks was analyzed using repeated measures analysis of covariance using pulse and blood pressure measures collected every 90 seconds throughout each five-minute recovery period, and a calculated average of each minute of continuously collected heart rate. Average means during recovery are reported below when the main (between subjects) effects are significant. Clear and consistent group differences were found, with the smiling groups showing lower levels of cardiovascular activity during the recovery period more closely approximating baseline levels of cardiovascular activity by the end of the recovery period as compared to the control group in both stress tasks. For complete results, see Table A1. For all analyses, pulse rate recovery results were also confirmed via heart rate using an electrocardiogram (ECG). (See Appendix D for graphs depicting these differences).

Following the star tracer task, the smiling groups ($M = 68.19$) showed lower levels of pulse during recovery than the control group ($M = 71.45$), $F(1, 117) = 3.95$, $p = 0.05$); the Duchenne groups ($M = 67.61$) showed marginally lower levels of HR during recovery than the Non-Duchenne groups ($M = 71.76$), $F(1, 60) = 3.38$, $p = 0.07$); the Duchenne groups ($M = 66.40$) showed lower levels of pulse during recovery than the control group ($M = 71.69$), $F(1, 74) = 6.71$, $p < 0.05$); and the Aware smiling groups ($M = 66.60$) showed lower levels of pulse during recovery than the control group ($M = 71.29$), $F(1, 72) = 5.40$, $p < 0.05$). When comparing three groups (neutral vs. Duchenne vs. non-Duchenne; and neutral vs. aware vs. non-aware) in the same model, significant pulse recovery differences were found between the control group ($M = 72.44$), non-Duchenne groups ($M = 69.36$), and Duchenne groups ($M = 66.25$), $F(2,97) = 4.63$, $p < 0.05$) as well as the control group ($M = 72.56$), aware smiling groups ($M = 66.84$), and non-aware smiling groups ($M = 68.63$), $F(2, 97) = 3.86$, $p < 0.05$).

Results for the cold pressor task recovery period followed the same pattern. The smiling groups (*M* = 67.37) showed lower levels of pulse during recovery versus the control group (*M* = 71.69), *F*(1, 109) = 4.34, $p < 0.05$); the Duchenne groups (*M* = 64.98) showed marginally lower pulse during recovery than the non-Duchenne groups (*M* = 69.32), *F*(1, 76) = 3.61, $p = 0.06$); the Duchenne groups (*M* = 66.17) showed lower HR during recovery than the non-Duchenne groups (*M* = 72.98), *F*(1, 54) = 8.18, $p < 0.05$); the Duchenne groups (*M* = 65.37) showed lower levels of pulse during recovery than the control group (*M* = 72.02), *F*(1, 69) = 9.12, $p < 0.05$); the non-aware smiling groups (*M* = 68.34) showed a marginally lower average pulse level during recovery than the control group (*M* = 72.52), *F*(1, 68) = 2.78, $p = 0.10$); and the aware smiling groups (*M* = 66.66) showed lower levels of pulse during recovery than the control group (*M* = 71.48), *F*(1, 66) = 4.61, $p < 0.05$). When comparing three groups in the same model, significant differences were found between the control group (*M* = 71.98), the smiling groups (*M* = 69.80), and the Duchenne groups (*M* = 65.18), *F*(2, 105) = 5.08, $p < 0.05$) as well as the control group (*M* = 72.29), Aware smiling groups (*M* = 65.86), and Non-aware smiling groups (*M* = 68.72), *F*(2, 105) = 3.67, $p < 0.05$).

Discussion

The purpose of this study was to examine the facial feedback hypothesis and the role of facial muscle activation as a buffer of the negative physiological effects of stress. Results indicated that individuals who activated the muscles involved in a smile throughout a stressful task reported a decrease in negative affect and less of a decrease in positive affect compared to the control group; thus, smiling through a stressful situation is associated with expected changes in affect, which supports the facial feedback hypothesis. These findings are consistent with recent literature showing that individuals who are unable to manipulate facial muscles show decreased ability to experience and respond to emotional stimuli (Ian Davis, Senghas, Brandt, & Ochsner, 2010).

When testing our hypotheses regarding the role of facial expression in the stress response, we found little evidence that expression influences the cardiovascular stress reactivity response. However, consistent with a single study showing that smiling naturally during stress “undoes the stress response” (Fredrickson & Levenson, 1998), our results consistently revealed that smiling returned participants towards baseline levels of cardiovascular activity faster than participants in the control condition, suggesting that activating the muscles involved in a smile may play some role in buffering the negative effects of stress by decreasing the time it takes to physiologically recover from a stressor. Because chopsticks were only placed in participants’ mouths during each stress task and were removed during both recovery periods, this suggests that smiling through a stressful event is protective for a period of time *after* both the stressor and the facial muscle activation has ended. These results support both Fredrickson and Levenson’s (1998) “undoing” hypothesis of PA, which suggests that PA plays a role in “undoing” the negative cardiovascular effects of stress, regardless of an individual’s perception of how stressful an event is (which was controlled for in our analyses), as well as Pressman and Cohen’s (2005) “stress-buffering” hypothesis, which states that positive affect primarily influences health by reducing the harmful effects of the stress response.

Although results indicated that participants in the Duchenne smiling conditions displayed increased cardiovascular stress reactivity throughout each task, this was not replicated across cardiovascular measures taken throughout the study, which makes this result difficult to draw concrete conclusions from. Although it is possible that activating the muscles involved in a Duchenne smile is associated with increased cardiovascular reactivity, it is also likely that a series of increased demands associated with this condition may have played a role in this outcome. First, the Duchenne condition required participants to place the chopsticks in their mouths in a manner that activated two muscle groups instead of one, which proved to be more tiring to do, as evidenced by significant differences between groups in terms of reported facial muscle fatigue (reported on a scale from 1 (not tired at all) to 5 (extremely tired)) throughout each task, with the Duchenne groups reporting more facial muscle fatigue following both stress tasks than the non-Duchenne and neutral groups (Star Tracer Task: $F(2, 150) = 2.95$, $p = 0.05$, Duchenne ($M = 2.22$), non-Duchenne ($M = 1.93$), neutral ($M = 1.67$); Cold Pressor Task: $F(2, 152) = 3.20$, $p < 0.05$, Duchenne ($M = 2.04$), non-Duchenne ($M = 1.86$), neutral ($M = 1.55$). Also, research assistants were required to repeat instructions up to three times throughout the tasks to participants having difficulty adhering to their conditions primarily due to facial muscle tire; thus, participants in the Duchenne condition were given more additional instruction than participants in the other conditions, which likely placed increased cognitive, physiological, and emotional demand on those participants throughout the tasks. Second, because participants in the Duchenne condition were required to complete both stress tasks while at the same time focus on manipulating the chopsticks in a way that activated two separate muscle groups, it is possible that this additional task played a role in the increased physiological stress response, suggesting that cognitive load may be responsible either fully or in-part for increased reactivity rather than facial muscle activation alone. Finally, a spurious finding in this case is possible, particularly because this was only one of nine tests examining differences between various group combinations that was significant. Furthermore, this finding was not replicated with other cardiovascular measures (e.g. pulse and other blood pressure measures). However, this could also be an important new finding, but because no previous published literature has shown an association between Duchenne smiling and cardiovascular stress reactivity, this needs to be further examined and replicated before concrete conclusions can be drawn from this finding.

Although support for the facial feedback hypothesis is not new (see Strack et al., 1988) nor is the association between positive emotion and faster cardiovascular stress recovery (see Fredrickson et al., 1998), the current study advances this literature through the additional examination of two types of smiling (Duchenne and non-Duchenne) as well as what role awareness of smiling plays in these outcomes. In regard to the two types of smiling, 1) Duchenne smiling was associated with faster stress recovery than the non-Duchenne smiling group and the control group after both stress tasks; and 2) Duchenne smiling was associated with greater stress reactivity than the non-Duchenne smiling group and the control group. This suggests that smiling is not only effective in speeding stress recovery but Duchenne smiling may be *more* effective than non-Duchenne smiling. In regard to awareness of smiling, no significant results were found in any analyses between these conditions, which suggests that regardless of intentionality, activating the muscles involved in a smile is associated with beneficial health outcomes. However, because previous literature has shown that "surface acting," (i.e. displaying expression and emotion incongruent with actual felt emotion) in customer service employees has been associated with higher burnout rates and increased error (e.g., Brotheridge & Grandey, 2002; Goldberg & Grandey, 2007), the benefits associated with smiling through stressful events must be interpreted with caution, and further research should examine in what contexts facial expression might be beneficial versus detrimental or whether there is some third factor contributing to the association between surface acting and burnout rates.

Overall, our results suggest that the benefits of smiling in general and particularly through stressful experiences should not be overlooked, as smiling is associated with beneficial state affect changes and faster recovery from stress. In short, the old adage “grin and bear it” *does* have proven value. However, because stressors in the lab can vary widely from stressors in everyday life, the generalizability of our findings is limited. Future research should further examine how facial feedback affects the stress response in various types of stressful situations and replicate these findings, especially since the significant results in terms of stress reactivity were not replicated between cardiovascular measures within the current study and the significant causal relationship between facial expression and stress recovery is still novel, with only one previous study suggesting an association (but no causal relationship) between spontaneous smiling and stress recovery (Fredrickson & Levenson, 1998).

Finally, although enduring “fake smiling” throughout an extended period of time, particularly when “forced,” has been found to be potentially detrimental, the current results suggest that smiling may be beneficial in recovering from brief painful stressors similar to the cold pressor task, such as receiving a shot or having blood drawn at the doctor’s office, as well as other brief stressful tasks involving mental and physical challenges similar to the star tracer task, such as those found on an academic exam. Furthermore, this association between facial muscle activation and faster stress recovery has important implications for individuals with facial paralysis who do not have the ability to utilize facial feedback in times of stress. Further research should seek to examine how muscular impairment in the face affects the stress response.

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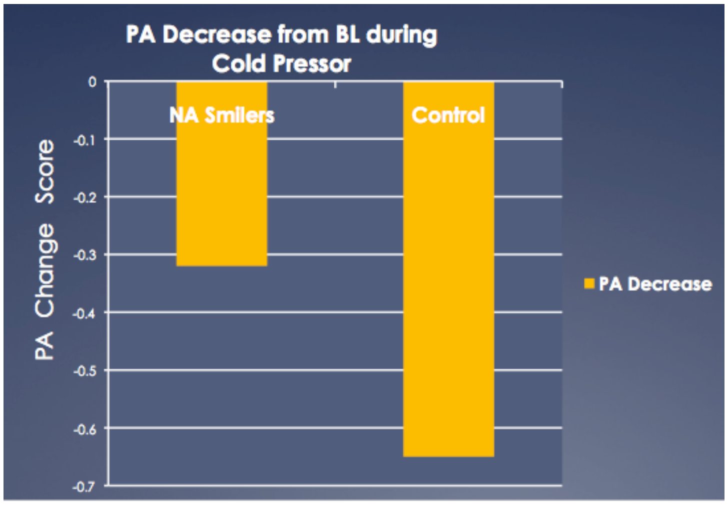
Appendix A: Stress Recovery Results

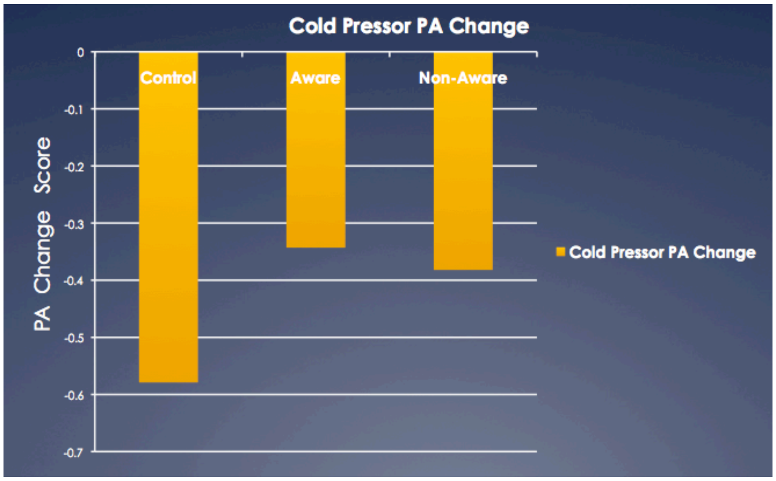
Table A1: Stress Recovery

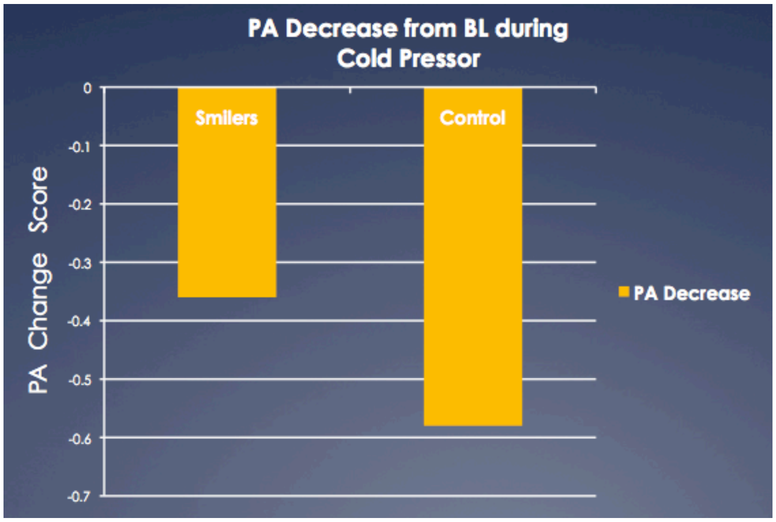
Groups Compared	**Task**	**Recovery Measure**	***df***	***F***	***p***
Smile (M=68.19) v. Control (M=71.45)	Star Tracer	Pulse	1, 117	3.95	< 0.05
Duchenne (M=67.61) v. Non-Duchenne (M=71.76)	Star Tracer	Heart Rate	1, 60	3.38	= 0.07
Duchenne (M=66.40) v. Control (M=71.69)	Star Tracer	Pulse	1, 74	6.71	< 0.05
Aware smile (M=66.60) v. Control (M=71.29)	Star Tracer	Pulse	1, 72	5.40	< 0.05
Non-Duchenne (M=69.36) v. Duchenne (M=66.25) v. Control (M=72.44)	Star Tracer	Pulse	2, 97	4.63	< 0.05
Aware smile (M=66.84) v. Non-aware smile (M=68.63) v. Control (M=72.56)	Star Tracer	Pulse	2, 97	3.86	< 0.05
Smile (M=67.37) v. Control (M=71.69)	Cold Pressor	Pulse	1, 109	4.34	< 0.05
Duchenne (M=64.98) v. Non-Duchenne (M=69.32)	Cold Pressor	Pulse	1, 76	3.61	= 0.06
Duchenne (M=65.37) v. Control (M=72.02	Cold Pressor	Pulse	1, 69	9.12	< 0.01
Non-aware smile (M=68.34) v. Control (M=72.52)	Cold Pressor	Pulse	1, 68	2.78	= 0.10
Aware smile (M=66.66) v. Control (M=71.48)	Cold Pressor	Pulse	1, 66	4.61	< 0.05
Duchenne (M=65.18) v. Non-Duchenne (M=69.80) v. Control (M=71.98)	Cold Pressor	Pulse	2, 105	5.08	< 0.01
Aware smile (M=65.86) v. Non-aware smile (M=68.72) v. Control (M=72.29)	Cold Pressor	Pulse	2, 105	3.67	< 0.05

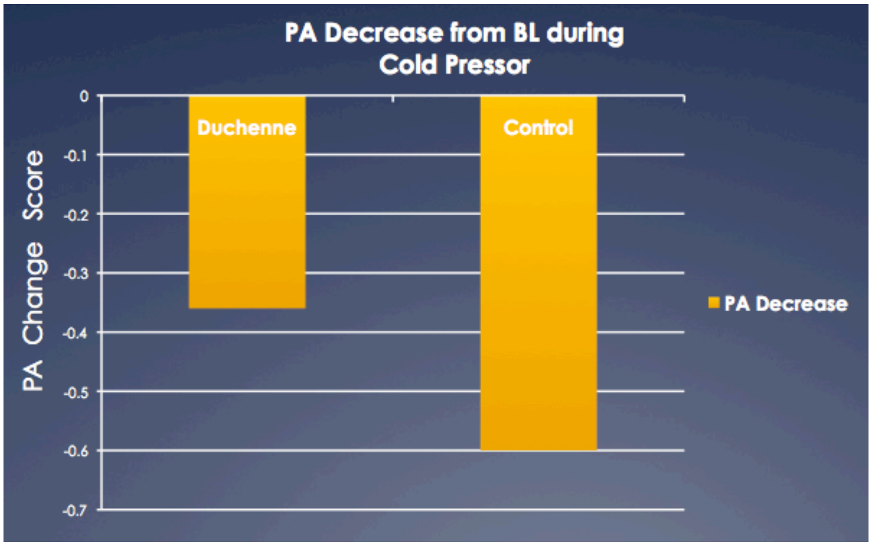
Appendix B: Affect Results

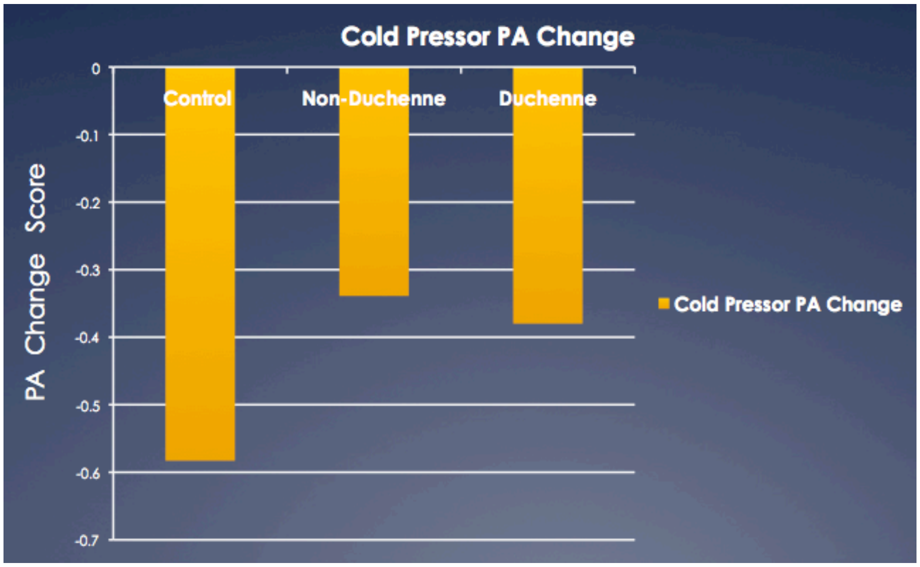
*Note: PA change scores can range from 0 to 28, and NA change scores can range from 0 to 48.

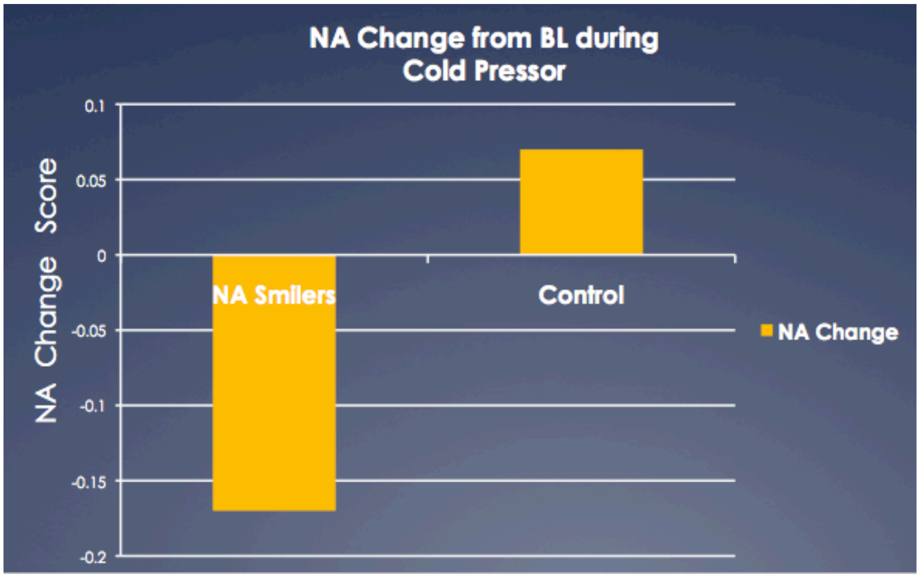


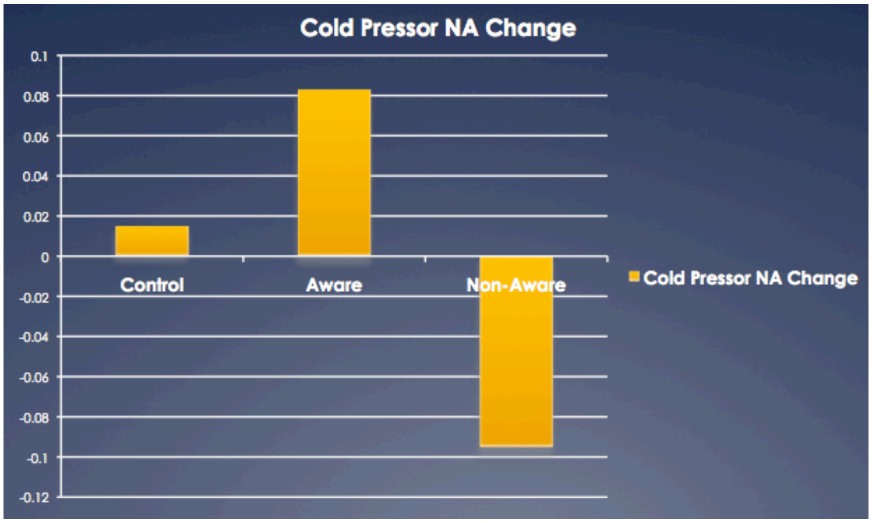


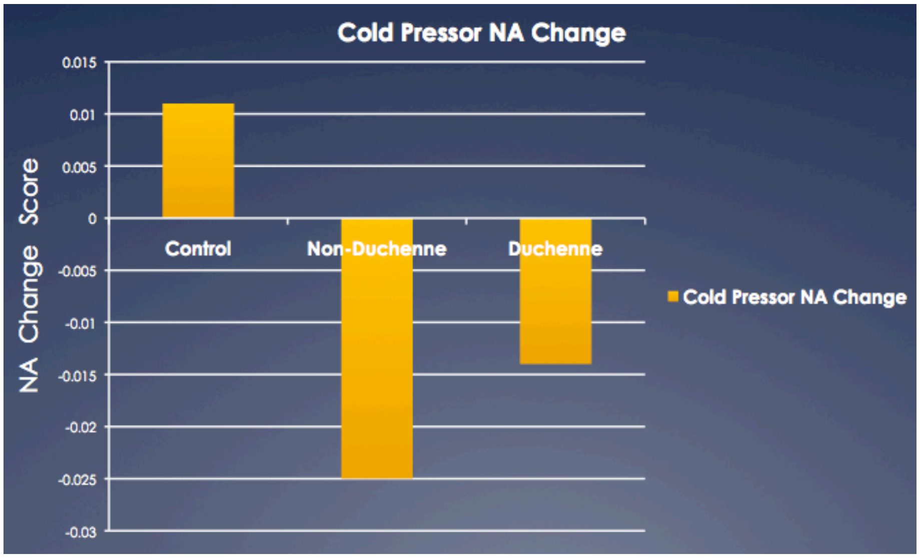


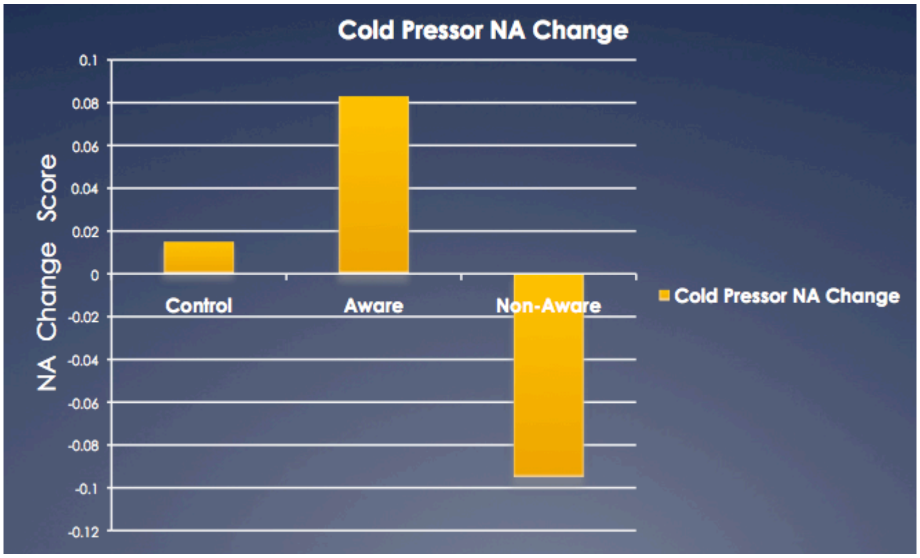

PA Decrease from BL during Cold Pressor
PA Change Score
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
Duchenne
Control
PA Decrease


Cold Pressor PA Change
PA Change Score
0
-0.1
-0.2
-0.3
-0.4
-0.5
-0.6
-0.7
Control
Non-Duchenne
Duchenne
Cold Pressor PA Change

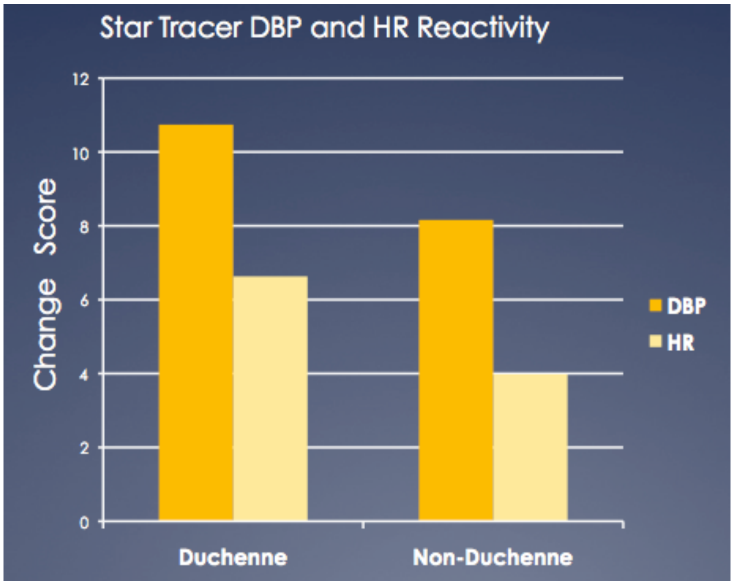

NA Change from BL during Cold Pressor
NA Change Score
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
NA Smilers
Control
NA Change

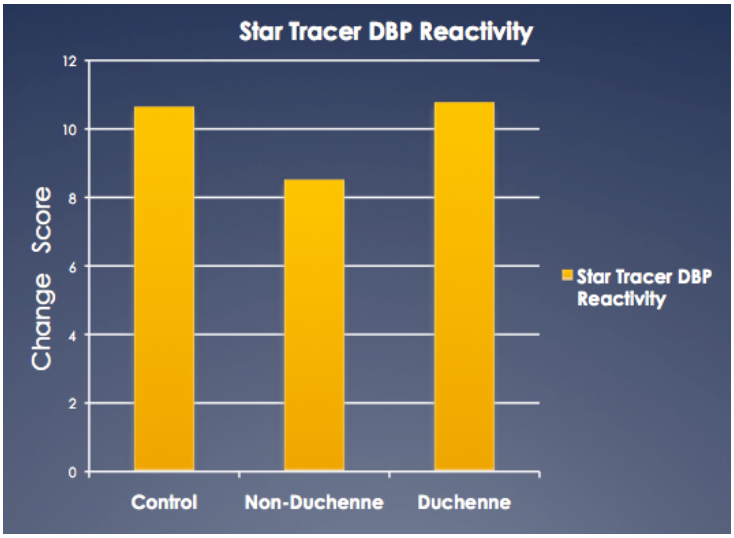

Cold Pressor NA Change
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
Control
Aware
Non-Aware
Cold Pressor NA Change

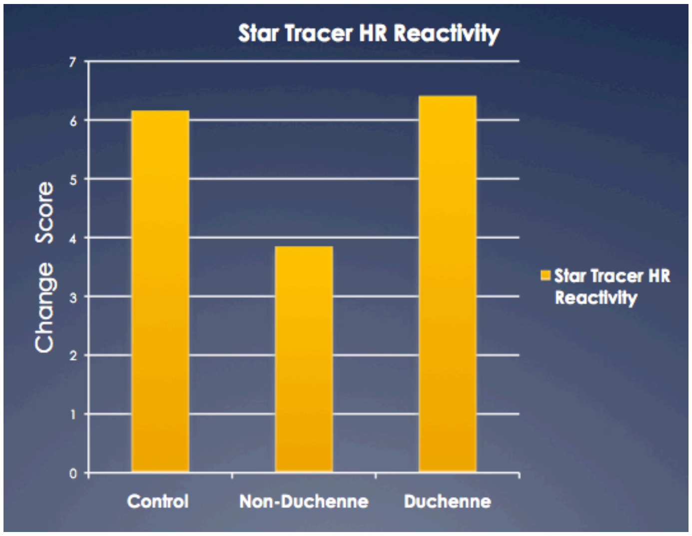

Cold Pressor NA Change
NA Change Score
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
Control
Non-Duchenne
Duchenne
Cold Pressor NA Change

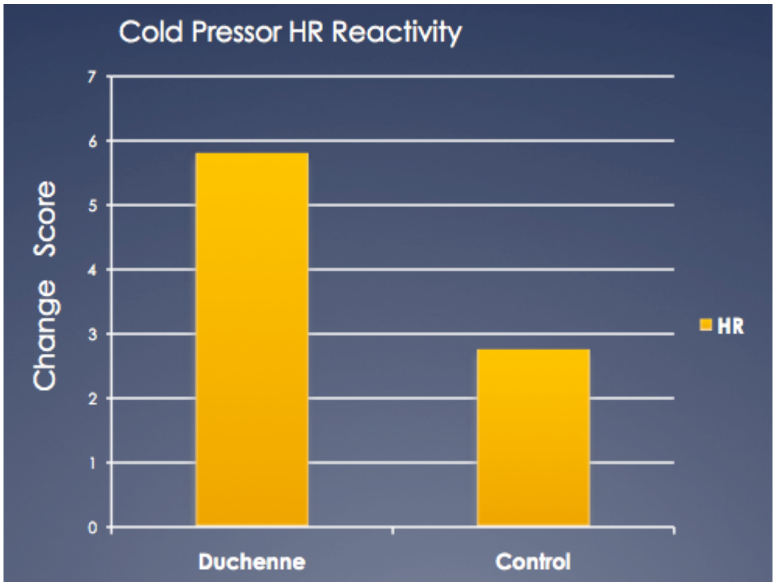

Cold Pressor NA Change
NA Change Score
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
-0.12
Control
Aware
Non-Aware
Cold Pressor NA Change

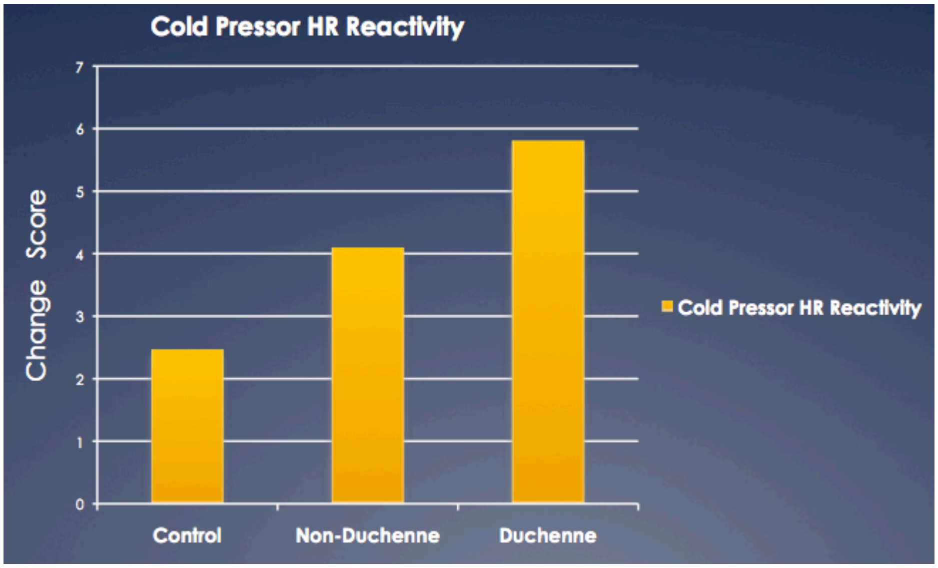
Appendix C: Reactivity Results



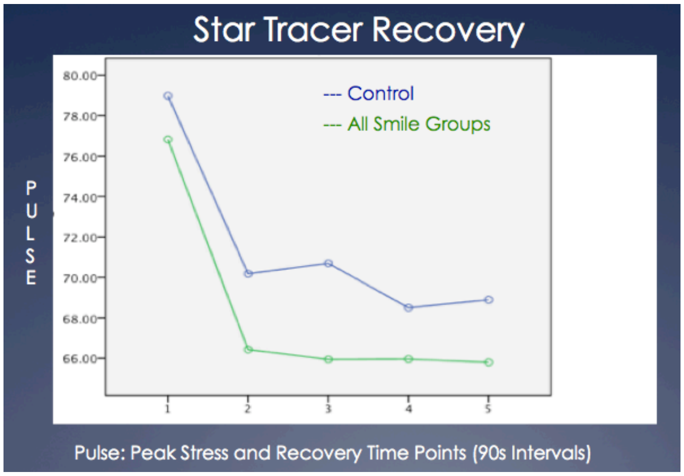





Cold Pressor HR Reactivity
Change Score
7
6
5
4
3
2
1
0
Duchenne
Control
HR

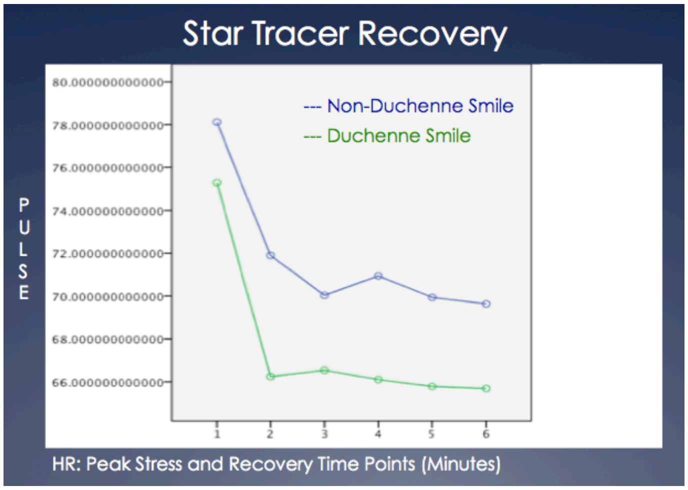

Cold Pressor HR Reactivity
Change Score
7
6
5
4
3
2
1
0
Control
Non-Duchenne
Duchenne
Cold Pressor HR Reactivity

Appendix D: Recovery Results



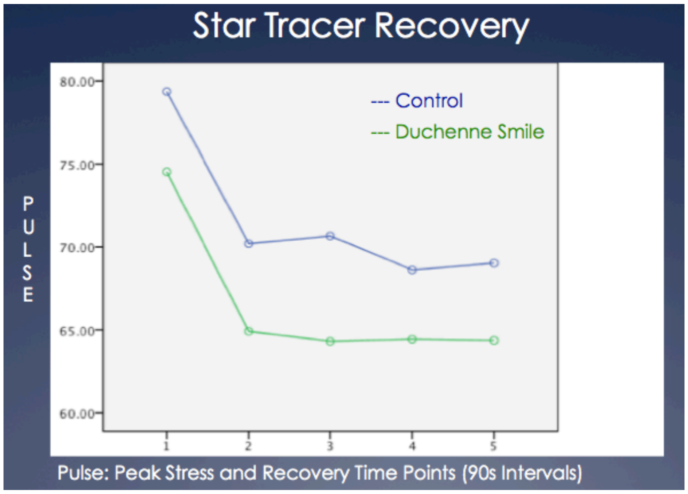
Star Tracer Recovery

Pulse: Peak Stress and Recovery Time Points (90s Intervals)



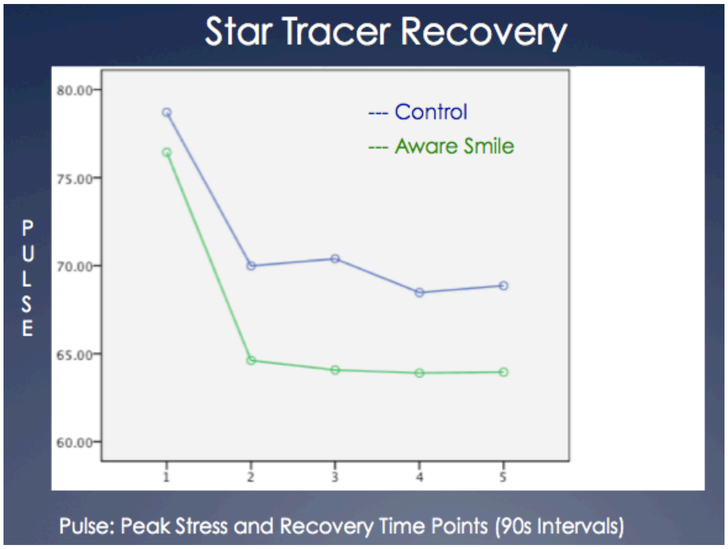
Star Tracer Recovery

HR: Peak Stress and Recovery Time Points (Minutes)



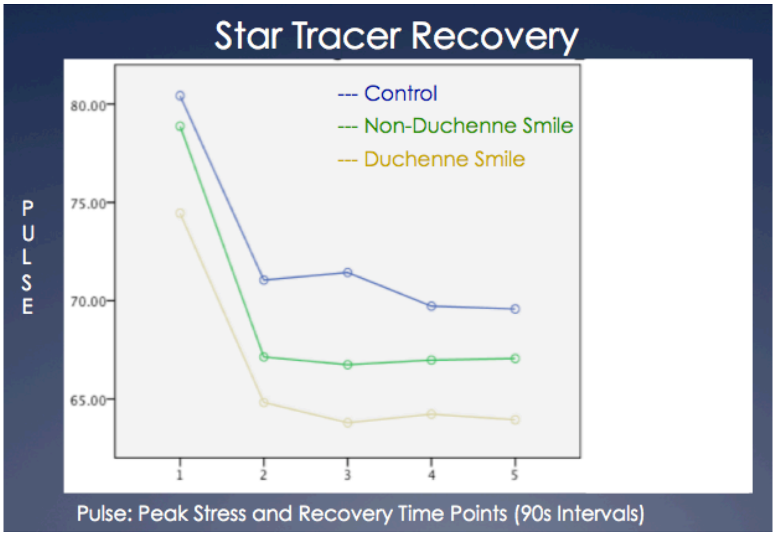
Star Tracer Recovery

Pulse: Peak Stress and Recovery Time Points (90s Intervals)



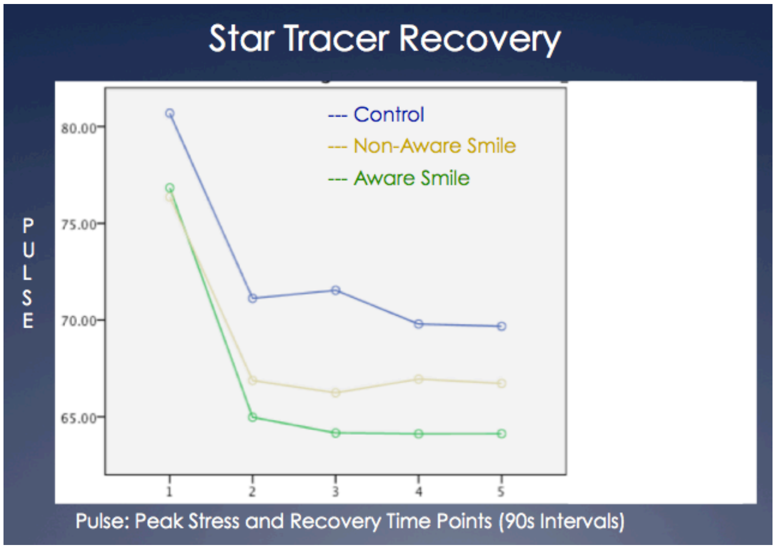
Star Tracer Recovery

Pulse: Peak Stress and Recovery Time Points (90s Intervals)



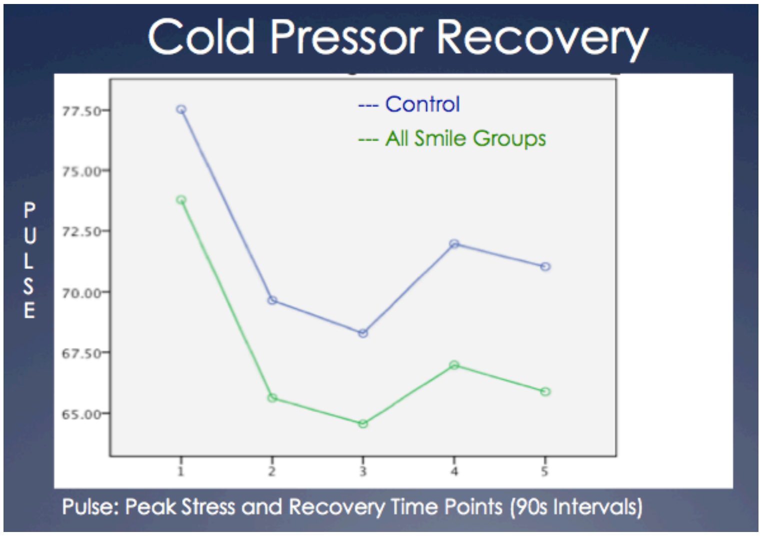
Star Tracer Recovery

Pulse: Peak Stress and Recovery Time Points (90s Intervals)



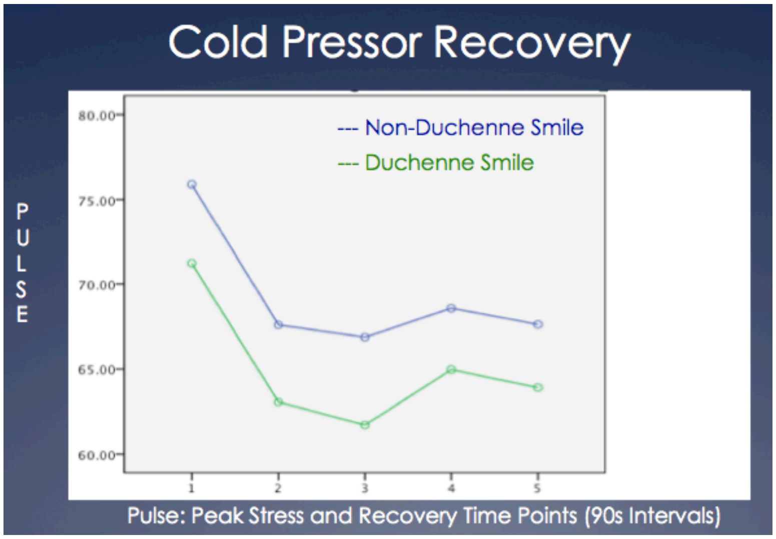
Star Tracer Recovery

Pulse: Peak Stress and Recovery Time Points (90s Intervals)



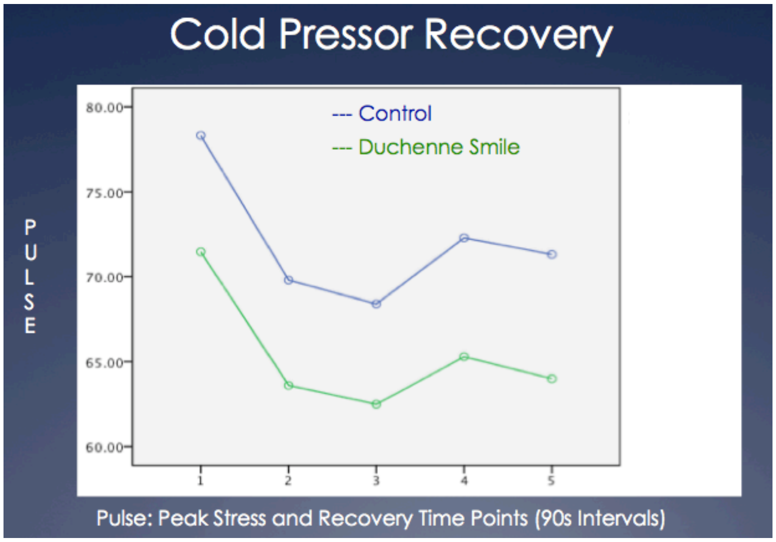
Cold Pressor Recovery

Pulse: Peak Stress and Recovery Time Points (90s Intervals)



Cold Pressor Recovery

Pulse: Peak Stress and Recovery Time Points (90s Intervals)



Cold Pressor Recovery

Pulse: Peak Stress and Recovery Time Points (90s Intervals)

Appendix E: Participant Instructions Throughout the Study

**All text in italics indicates verbal instruction from a research assistant to a participant

Introduction to Study: *The purpose of this study is to examine multitasking ability; specifically how multitasking affects performance as well as what role demographic and psychological characteristics play in different types of tasks.*

You will be asked to complete a number of tasks in this study simultaneously, including a pencil manipulation task, cold temperature sensory task and a mechanical arm movement task. You will first complete a number of questionnaires. Then, you will be hooked up to electrodes and a blood pressure cuff so that we can measure your physiological reactions to various tasks over the course of the study.

There is little risk associated with this study. Primarily, your skin may be slightly red from the electrode adhesive and you may feel some discomfort from the blood pressure cuff. If you decide that you do not want to participate in this study, you are free to withdraw at any time. You will be awarded 3 credits for participating. Please read the consent form and sign at the end if you would like to participate.

Placement of Physiological Recording Equipment:

EKG and respiration measures**:** *Now I am going to stick 5 electrodes on your chest and 2 on your back so that we can record your heart rate and breathing.*

Blood Pressure cuff: *Are you right or left handed? (*blood pressure cuff placed on the dominant hand*). This cuff is automatic. You will know when it is recording your blood pressure because you will feel it inflate on your arm. This will happen at various times during the session. When you feel the cuff inflate, try not to move your arm. The cuff will feel tight, especially the first time it inflates. Please keep your arm extended throughout the study.*

Assignment of Condition:

Facial Manipulation: *In order to examine how multitasking affects performance, I am going to ask you to perform a pencil manipulation task at the same time you will be performing a series of other tasks.*

Please place this pencil in your mouth exactly as you see me doing so before we begin the other tasks (Research Assistant demonstrates condition)*.* \

Instructions by Condition:

(All instructions repeated up to three times throughout the study to increase adherence)

NEUTRAL: *Please hold this pencil gently with your front teeth.*

SMILE (**not** aware): *Please hold this pencil tightly with your mouth open.*

Duchenne SMILE (**not** aware): *Please hold this pencil sideways in your mouth tightly and push it back as far as it can go.*

SMILE (**aware**): *Please hold this pencil tightly with your mouth open. At the same time, please smile gently and naturally.*

Duchenne SMILE (**aware**): *Please hold this pencil sideways in your mouth tightly and push it back as far as it can go. Notice in this picture* (Research Assistant points to image of a Duchenne smile) *the crinkle around the eyes. Please smile as naturally and big as you can while holding this pen so that you also produce a crinkle around your eyes.*

You will be asked to perform this task with the pencil throughout the study with intermittent breaks.

Baseline Instructions:

OK, we are ready to start the study, which will begin with a 10 minute, undisturbed resting period. Toward the end of this period, we will be taking measures and you will feel the cuff inflate. Please try to keep your arms still at that time. Please keep your dominant hand as still as possible. Just sit back, relax, and breathe normally. Please do not elevate your feet in the chair, just sit quietly. Do you have any questions?

***POMS instructions:** (repeated before and after each stress task) *Here is a questionnaire for you to complete. Please fill it out as quickly as possible based on your gut instinct.*

Star Tracer Instructions: *As I said before, we are testing multitasking ability today, so you will need to hold the pen in your mouth as I have instructed you while performing this star-tracing task. The average person is able trace this star 8 times in 2 minutes, making fewer than 25 mistakes. If you can trace this start 8 or more times in 2 minutes with 25 or fewer mistakes, you will receive a prize at the end of the experiment today. Please grab the stylus with your non-dominant hand and place it inside the metal box. Notice the mirror image of a star. When I say "go," trace the image of the star as quickly as you possibly can while staying within the lines. This box here will display your errors. Do you have any questions? Please begin the pencil holding task now.* Research Assistant says *GO* and times the task. After the task, the research assistant says, *You may stop the pencil holding task at this time.*

***POMS instructions**

Cold Pressor Instructions: *Please begin the pencil holding task as you did before. When I say "go," please place your non-dominant hand in this bucket of ice water until I tell you to remove it. If at any point this task becomes too uncomfortable and you don't feel able to finish, please alert me right away. Do you have any questions? Ok, "GO."* Research Assistant times the task for one minute and at that point says, *Please remove your hand from the water and stop the pencil holding task.*

***POMS instructions**

Debriefing Instructions: *The true purpose of this study is to better understand the facial feedback hypothesis (FFH) and how it influences responses to stress. The FFH states that* *activating facial muscles can influence a person's emotions. By placing the pen in your mouth in the way we instructed you, specific facial muscles were activated throughout the experiment today. We are interested in examining how this affected your response to the two brief stress tasks we asked you to complete. You should know that we were intentionally trying to increase your stress levels and that the researchers correcting you during the tracing task were not actually evaluating your performance. You performed very well, and we appreciate your participation.*

We told you that the purpose of our study was to examine muscle movement and multitasking ability because if you had been aware that we were actually interested in your facial expression, it may have influenced how you reacted to our tasks and responded to our questionnaires. Every participant in this study received the same information regarding the study's purpose before participating and was led to believe the same story.

You were placed in a group testing one of four facial conditions tested in this study: (1) muscles activated during a real smile (2) muscles activated in a fake smile (3) muscles activated in a frown and (4) muscles activated with neutral expression. We hope to use this information to better understand whether facial muscle activation, especially during a real smile, can buffer the effects of stress and perhaps to design interventions in the future that will help people manage stress better.

As stated earlier on the consent form, you had the right to withdraw at any time and may ask that your data not be included now that you know the true purpose of the project. If you have any further questions, please use the contact information on your copy of the consent form.

Do you have any questions? Thank you for participating. Don't forget your copy of the consent form.