Psychophysiology, *39* (2002), 397–405. Cambridge University Press. Printed in the USA.

DOI: 10.1017.S0048577201393150

Difficulty does not account for emotion-specific heart rate changes in the directed facial action task

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Abstract

Boiten (1996) used the Directed Facial Action task (a task we developed in which participants follow instructions, based on theory about how emotion is expressed in the face, to move facial muscles deliberately to produce different facial configurations) to investigate heart rate differences among six emotional configurations. Boiten's findings closely replicated ours (Levenson, Ekman, & Friesen, 1990) in terms of heart rate change, self-reported emotion, and rated difficulty during the configurations. Boiten concluded that differences in difficulty were responsible for found differences in heart rate; in contrast, we had concluded that heart rate findings could not be explained in this manner. In this paper, we argue that neither Boiten nor we did the critical analyses needed to determine whether heart rate changes were mediated in this way. Performing these analyses, we conclude that neither reported difficulty nor two other potential mediators (time required to make the facial configurations; activity of nonfacial muscles) mediated the heart rate differences that we found between emotional configurations in the Directed Facial Action task.

Descriptors: Emotion, Autonomic nervous system, Specificity, Directed facial actions, Effort/difficulty

Ekman, Levenson, and Friesen (1983) developed the Directed Facial Action task as a tool to help study the relationship between facial, autonomic, and experiential aspects of emotion. In this task, participants are instructed to move their facial muscles voluntarily in ways that produce facial configurations that represent prototypical emotional facial expressions. In a series of studies using this task, we concluded that these emotional configurations produce different patterns of autonomic nervous system activity and, under certain conditions, subjective emotional experience as well (Ekman et al., 1983; Levenson, Carstensen, Friesen, & Ekman, 1991; Levenson et al., 1990; Levenson, Ekman, Heider, & Friesen, 1992). Subsequently, Boiten (1996) adopted this task to study heart rate, respiratory, and self-reported emotional responses. As we will indicate below, the findings from our studies and from Boiten's study are essentially identical in terms of the effect that the Direct Facial Action task has on heart rate and on self-reported emotion. Boiten, however, argued that the heart rate differences among the emotional configurations could be explained in terms of differences in the difficulty of making the configurations. In our studies, having attempted to eliminate that possibility (and a number of other potential mediators), we argued that it was the emotions associated with each of the configurations that was responsible for the cardiac differences. Our argument was based on the view that: (a) making emotional facial expressions can evoke other aspects of emotion including autonomic physiology and subjective emotional experience; (b) autonomic differences between emotions reflect differences in the cardiac support needed for prototypically adaptive associated behaviors; and (c) emotions like fear and anger, which are associated with prototypically adaptive behaviors like fighting and fleeing, call forth higher levels of cardiac activation than emotions such as disgust and happiness, which are associated with behaviors that make lower cardiovascular demands.

In the present paper, we will attempt to delineate the extent to which Boiten's work and ours converge on the same findings. In recent years, the study of mediating variables has become more formalized (e.g., Baron & Kenny, 1986); thus, we will also provide the critical mediational analyses not conducted either by us or by Boiten that should help settle the issue of whether the cardiac findings were mediated by differences in the difficulty of making the different facial configurations.

The Original Studies: Methods and Results

A brief description of our methods and results may be helpful for those readers not familiar with the original studies.

Methods

Participants come to the laboratory and have sensors attached to record a number of autonomic, respiratory, and somatic measures thought to be related to emotion. In the Directed Facial Action task participants are given very specific muscle-by-muscle instructions

This research was supported by grant MH50841 from the National Institute of Mental Health and grant AG17766 from the National Institute on Aging to the first author.

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(e.g., "raise your brows," "draw them together," etc.), which, if followed correctly, result in the production of a facial configuration that resembles a prototypical emotional expression.[1] The experimental session is organized into trials, each consisting of a resting baseline, instructions to produce a nonemotional facial configuration (to provide a comparison period of physiological activation associated with the same nonemotional facial configuration on each trial), a rest period, instructions to produce an emotional facial configuration, a rest period, and finally, a series of queries concerning subjective emotional experience, effort or difficulty, and associated thoughts and sensations. An experimenter, viewing the participant's face on a video monitor, provides coaching as needed to help the participant comply with the instructions (e.g., "raise your brows, but don't bring them together"). Configurations—both nonemotional and emotional—are held for 10 s, which provides the time window used for extracting and averaging the physiological measures. Each participant repeats this sequence for a counterbalanced series of emotional configurations that includes anger, disgust, fear, happiness, sadness, and surprise.

Results

Across our series of studies, the most consistent finding was that voluntary facial actions produced a small set of reliable autonomic differences among the negative emotions of anger, disgust, fear, and sadness and between these negative emotions and the positive emotion of happiness. The key aspect of these results as regards Boiten's challenge was that the configurations associated with anger, fear, and sadness produced greater increases in heart rate than the configuration associated with disgust, with the configurations associated with happiness and surprise falling in between.

In considering what might be responsible for these cardiovascular changes, we concluded that it was the *emotion* associated with each of the configurations (Levenson et al., 1990). Before embracing this conclusion, we evaluated a number of alternative (and arguably more parsimonious) hypotheses that implicated possible indirect mediators of the physiological findings. This included evaluating differences in the difficulty of making the various configurations and the possible role of concomitant muscle activity, which is always important to consider when heart rate changes are involved (Levenson, 1979; Obrist, 1981). We also conducted tests of the generalizability of our findings across subject variables such as age, profession, gender, and culture.

The findings from these additional tests of mediators and generalizability indicated that the differences in cardiovascular activity associated with different emotions in the Directed Facial Action task (a) cannot be accounted for by the difficulty of making the emotional configurations, concomitant nonfacial muscle activity, seeing one's face in a mirror, or identifying the target emotion from the instructions to move the facial muscles (Levenson et al., 1990); (b) are generalizable in pattern across age, profession, gender, and culture (Ekman et al., 1983; Levenson et al., 1990, 1991, 1992); and (c) are similar to those produced using more "conventional" emotion-eliciting tasks such as imagery, films, and situational manipulations (Levenson, 1992; Levenson et al., 1991).

[1]The Directed Facial Action task is not the same as a "posing" task in which subjects are given the name of an emotion and simply asked to show that emotion on their face. In the Directed Facial Action task the emotion is never mentioned and the configuration is constructed step-by-step using instructions.

Reactions

In the 45 years since Ax (1953) conducted his landmark study of fear and anger, there have been many investigators who have reported single studies of autonomic specificity, but surprisingly few sustained programs of published work. In a series of studies, we evaluated the Directed Facial Action task in five different samples (three young American adults, one elderly American adults, one young adults from a non-Western culture). Nonetheless, autonomic specificity is a highly contentious and methodologically difficult issue in emotion research, and we utilized a novel method of emotion elicitation (i.e., the Directed Facial Action task). Thus, the research was clearly fair game for criticism and debate (e.g., are the controls adequate? Are other interpretations of findings viable and more parsimonious?) and it generated its share of controversy, both formal (e.g., Zajonc & McIntosh, 1992) and informal.

Until Boiten's paper, few new data were reported that were relevant to the fundamental theoretical and empirical issues involved in using directed facial actions to study emotion-specific autonomic activity and emotional experience. For this reason, it seems important to comment on what we believe Boiten has found, what he has not found, what his work means for the research we have previously published, and the implications of his and our work for the general issue of autonomic specificity in emotion.

Boiten's Study

A Close Methodological Replication

Boiten's study shared a number of key features with ours. Over the years, we have provided many investigators with the exact instructions we developed for producing the six emotional and two nonemotional facial configurations (a fairly easy configuration we used as a control configuration prior to each emotional facial configuration, and a more difficult configuration we developed as a control for "effort" that we have not published on). Boiten used our instructions for his emotional and nonemotional configurations; thus this aspect of our methodology was identical. Other similarities were that we both pretested participants to find those who were good at voluntarily producing specific facial movements on request, we both had a "coach" who provided participants with instructions and feedback for making the configurations, and we both had each participant make all of the facial configurations (thus, in all analyses from both laboratories, "emotion" is always a within-subject factor).

There were also a number of differences in method. First, Boiten had participants hold their facial configurations for 30 s (to accommodate his respiratory measures) versus our 10 s. However, his heart rate measures were obtained during the first 10 s as were ours, thus minimizing this difference. Second, Boiten had participants rate the "effort" required to make a facial configuration, whereas we had participants rate the "difficulty" in making a configuration (there is some ambiguity here because Boiten uses the terms "effort" and "difficulty" interchangeably in his report). Third, Boiten obtained his effort ratings on a second set of trials (in which configurations were held for 10 s) that took place *following* the trials on which the physiology was analyzed. Thus, Boiten's effort ratings and physiological data came from different sets of configurations, whereas our difficulty ratings and physiological data came from the same set of configurations. Because of this, Boiten's effort ratings reflected whatever gains, losses, or error accrued from having made all of the facial configurations previously. Fourth, we coded participants' facial performances to determine how well they were able to make the required configurations (hereafter referred to as configuration "quality"). Boiten did not report conducting such quality scoring. This was an important difference because we found high configuration quality to be associated with greater autonomic differentiation among configurations and greater likelihood of participants' reporting experiencing the associated emotion. Further, configuration quality is clearly related to participants' difficulty ratings, but in a way that may not be intuitively obvious. In our work, quality and difficulty have always been *inversely* related, that is, participants who produce high quality configurations report the task to be *easier* than those who produce low quality configurations, $r = -.48$ over all configurations. Thus, if Boiten included all trials in his analyses, regardless of quality, this could potentially have made a difference in his heart rate, self-reported emotion, and effort findings.

Last, there were differences in the physiological measures between his and our studies. We measured surface temperature (which ended up making important distinctions between fear and anger) and muscle activity, neither of which Boiten included. Boiten derived an extensive set of respiratory measures (calibrated across participants) versus our only measuring respiratory period and depth (uncalibrated across participants).

In all, there were certainly enough similarities in procedures to make this a fair replication of our work and yet enough differences to provide a reasonable test of generalizability as well.

A Very Close Replication of Findings

True replication studies are quite rare in the literature; thus, standards for judging their success or failure can be somewhat subjective. However, in this case, using any reasonable standards, Boiten's findings clearly replicated ours in terms of heart rate changes, self-reported emotional experience, and rated difficulty of making the configurations.

Heart rate differences among emotions. Figure 1 presents the heart rate changes that occurred during the six emotional configurations in Boiten's work and in our first study (Ekman et al., 1983). This figure recreates the right-hand panel of the second figure in Boiten's (1996, p. 126) article. Visual examination will reveal the striking similarities between these two sets of heart rate data. Reflecting this, the correlation between the emotion means for the two studies is large and significant, $r = .94$,[2] $p = .005$. Both studies reported significant main effects for emotion and followed these up with pairwise comparisons. Boiten reported finding that the three negative emotions of anger, fear, and sadness all showed significantly larger cardiac accelerations than the negative emotion of disgust. These are the same differences among these four negative emotions that we reported in our studies (Levenson et al., 1990) and that are also found in the work of many others using different eliciting methods (Levenson, 1992).

Figure 1. Heart rate change during emotional configurations in the Directed Facial Action task from Ekman, Levenson, and Friesen (1983) and Boiten (1996). Standard errors of the mean are indicated for the Ekman et al. data.

Reported experience of the target emotion. Boiten found that subjects reported experiencing the target emotion associated with the facial configuration on 41.1% of trials, which is significantly greater than chance levels (set at 16.7% or one of six emotions). In all three of our experiments using young American subjects (Levenson et al., 1990), subjects also reported experiencing the target emotion associated with the facial configuration at greater than chance levels. Aggregating across our three experiments, subjects reported the target emotion on 33.5% of trials, which is also greater than chance, $z = 8.70$, $p < .001$. The difference between Boiten's 41.1% and our 33.5% is not significant, $z = 1.36$. Lastly, the intensities of the reported target emotions were similar between Boiten's study (3.6 on a 0–8 scale) and our two studies in which intensity ratings were obtained (4.8 on Experiment 2 and 3.8 on Experiment 3 in Levenson et al., 1990).

Thus, as was the case with the heart rate differences among emotional configurations, Boiten's findings regarding the emotional self-report produced using the directed facial action task closely replicated ours.[3]

Reported difficulty/effort of making the emotional configurations. Boiten found that subjects' effort ratings differed for the six emotional configurations (i.e., a significant main effect for emotional configuration). Exploring this further using pairwise comparisons, he found that (a) fear and sadness were rated as requiring more effort than disgust, happiness, and surprise; and (b) anger was reported to require more effort than happiness and surprise (anger did not differ from disgust). This suggests three levels of effort: fear and sadness requiring the most, then anger and disgust, and then happiness and surprise. Looking at the correlations between effort and heart rate change within each configuration, Boiten found that none was significant save for anger, $r = .47$, $p < .05$.

Comparing Boiten's findings with the difficulty ratings in Levenson et al. (1990), we also found a significant main effect for

[2] We were not able to obtain a copy of Boiten's data; thus this correlation was computed by measuring the bars in the graph in his article.

[3] Boiten noted that the directed facial action task produces reports of the target emotion less than half the time. Nevertheless, the target emotion was reported at greater than chance levels in all four studies (Boiten's one and our three). Because we do not regard self-report as the *sine qua non* of emotion, we were less concerned than Boiten about the fact that subjects reported the target emotion only on some, but not on the majority of trials.

Boiten also noted that the intensity of the reported affect was low (essentially one-third of the full rating scale). The Directed Facial Action task does not produce extremely intense emotional reports, but that is true of many other laboratory elicitors as well. The consistency of emotional reports produced by the Directed Facial Action task is nevertheless impressive. In our work (Experiments 2 and 3 in Levenson et al., 1990), for all six configurations, the intensity of the target affect when reported was significantly greater than 0 [anger: $t(14) = 8.91$; disgust: $t(16) = 10.83$; fear: $t(15) = 6.01$; happy: $t(22) = 13.43$; sadness: $t(13) = 8.43$; surprise: $t(21) = 10.72$; for all t tests, $p < .001$].

emotional configuration. Pairwise comparisons revealed that (a) fear and sadness were rated as more difficult than anger and disgust; and (b) anger and disgust were more difficult than happiness and surprise. This suggests the same three levels of difficulty: fear and sadness the most difficulty, then anger and disgust, and then happiness and surprise. As for the correlations between difficulty and heart rate changes for each configuration, we found none to be significant (anger: $r = .10$; disgust: $r = -.15$; fear: $r = -.17$; happiness: $r = -.33$; sadness: $r = .24$; surprise: $r = .16$) versus the one significant correlation for anger that Boiten found.

As indicated earlier, we only included high quality configurations in the analyses reported in our papers. We did this precisely to reduce the impact of effort-related confounds that could have elevated heart rate (e.g., frustration experienced by subjects who were not able to produce high quality configurations). Boiten did not use quality ratings, and thus his data include subjects who presumably were not able to follow the instructions in the task and would be expected to report expending greater effort. Supporting this scenario, our mean difficulty ratings were consistently lower than Boiten's (see Figure 2). Nonetheless, the pattern of difficulty ratings across the six configurations was essentially identical, as reflected in the correlation between his ratings and ours, which was large and significant, $r = .91$, $p = .012$.

Thus, as was the case with the heart rate data and the emotional self-report data, Boiten's findings regarding configuration difficulty closely replicated ours.

Within-individual analyses. Boiten computed what he termed "within-individual" correlations by calculating for each subject the correlation between reported effort and heart rate change across the six emotional facial configurations. He found that these correlations varied from $-.39$ to .82, with a mean $r = .32$ [a positive correlation indicates that higher effort ratings were associated with greater increase (or lesser decrease) in heart rate]. For purposes of comparing our results with Boiten's, we conducted a new set of analyses (using data from Experiment 3 in Levenson et al., 1990), finding that similar "within-individual" correlations between difficulty ratings and heart rate change in our data varied from $-.61$ to .77, with a mean $r = .18$. Thus, both we and Boiten found these correlations to be highly variable from subject to subject, with the average relationship small, but positive. Using a one-sample t test,

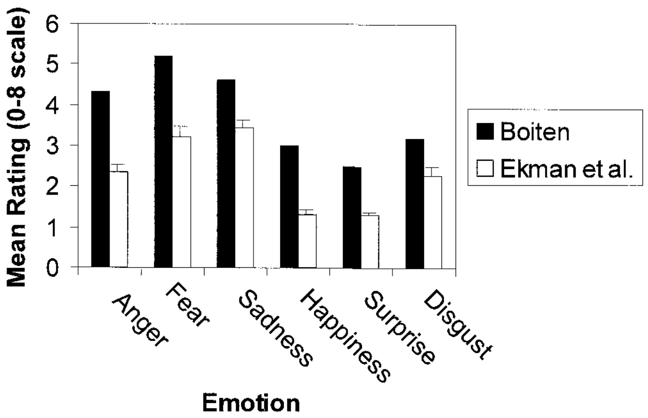

Figure 2. Configuration difficulty/effort ratings in the Directed Facial Action task from Levenson, Ekman, and Friesen (1990) and Boiten (1996). Standard errors of the mean are indicated for the Levenson et al. data.

Boiten reported that his set of within-individual correlations (converted to z scores) differed from 0, $t(14) = 3.24, p < .01$. It should be noted that this test only indicates that the z scores differ from 0 and not whether the average correlation is significant (arguably the more appropriate statistical test). In fact, Boiten's average correlation of .32 with $N = 15$ is not significant. We performed similar analyses and found that our set of within-individual correlations (converted to z scores) also differed from 0, $t(29) = 2.39$, $p = .02$, and that our average correlation of .18 with $N = 30$ was also not significant.

Boiten also conducted similar within-subject analyses involving his respiratory measures. Again these correlations ranged in size and sign across subjects, with the average correlation being positive between heart rate change and functional residual capacity (i.e., an estimate of the volume of air retained in the lung following expiration derived from surface strain gauges; $r = .35$) and between heart rate change and inspiratory pause duration ($r = .54$). In our work we did not measure these particular respiratory parameters; thus, a test of replication is not possible.

All of the findings from these within-individual analyses are consistent with what is known about the relationship that effort and respiration have with heart rate (e.g., faster respiration rate associated with faster heart rate in Levenson, 1979). However, their use to settle the question of potential mediators of heart rate change in the Directed Facial Action task is problematic for two reasons. First they do not provide a formal test of mediation (see Discussion below). Second, they do not insure that the high effort ratings and elevated respiration levels for a given participant occurred on those emotion trials found to have high heart rate in the group data (i.e., anger, fear, and sadness). Thus, to the extent that individual participants had their highest difficulty ratings or most elevated respiration levels on other emotion trials (e.g., disgust), the within-individual correlations would be uninformative for the primary issue at hand—determining whether differences in heart rate change among the emotional configurations in the Directed Facial Action task were mediated by effort or respiration. For these reasons, we will not weight the within-individual correlations heavily in the discussion that follows. Instead we will give greater attention to the formal analyses of mediation and to between-subjects analyses that allow direct tests of levels of potential mediators associated with the different emotional configurations.

Possible Mediators: Respiration and Effort

Thus far, we have summarized the work of two research groups who conducted essentially the same study and found essentially the same results. However, the interpretations of these very similar findings diverged quite sharply. The central thrust of Boiten's (1996) argument is that the heart rate differences among facial configurations produced by the Directed Facial Action task are mediated by respiration or effort or both. A critical examination of this conclusion is warranted.

Respiration

Much of Boiten's article is devoted to describing his careful respiratory measurement procedures, which produced six parameters of respiratory timing and volume using calibrated strain gauges. Importantly, the preponderance of his significant respiratory findings did not reveal differences in respiration among the emotional configurations, but rather revealed effects that (a) were common to all of the emotional configurations (i.e., differences between the control and emotional configurations on four of six parameters), or (b) were found in the within-subject correlations (correlations with effort ratings for one parameter, and correlations with heart rate for two parameters as described earlier).

Relationships between respiratory variables, effort ratings, and heart rate across all emotional configurations and within individuals are important for helping us understand aspects of the cardiac–respiratory-effort relationship. Nevertheless, they cannot settle the question of what accounts for cardiac differences among the different emotional configurations in the Directed Facial Action task. Findings of differences in respiratory variables *between* the emotional configurations, however, would be informative in this regard.

Boiten did find three respiratory differences between the emotional configurations: (a) Length of expiration was longer during the disgust configuration than during the anger and fear configurations; (b) length of respiratory cycle was longer during the sadness configuration than during the happiness configuration; (c) functional residual capacity was greater during the fear configuration than the other five configurations.

These findings do not make a strong case for mediation by respiration of the heart rate differences among emotions in the Directed Facial Action task. The length of expiration findings make the best case, because heart rate usually does slow during the expiratory phase of the respiratory cycle compared to the inspiratory cycle. Thus, a longer expiratory cycle during the disgust configuration might contribute to the slower heart rate found for this configuration compared to the anger and fear configurations.

However, the other two findings argue against the mediational hypothesis. A longer respiratory cycle during sadness than happiness should be associated with *slower* heart rate during sadness than happiness, but both Boiten and we found the opposite (faster heart rate in sadness than happiness). The functional residual capacity finding does not match up with any of his or our findings. For example, neither he nor we found differences in heart rate between fear, sadness, and anger, but Boiten found differences in residual capacity among the three.

Thus, in terms of understanding the found differences in heart rate between emotions in the Directed Facial Action task, the results from this extensive battery of respiratory measurements boils down to one parameter that *could* account for the finding of slower heart rate for disgust than for anger and fear. However, as we will point out shortly, demonstrating a difference between emotions in one physiological measure (e.g., respiratory cycle length) does not necessarily mean that this difference cancels out differences that are found between emotions in another physiological measure (heart rate). To determine this requires a formal test of mediation.

Effort/Difficulty

From the outset, we had been very concerned that heart rate changes produced by the Directed Facial Action task resulted from extraneous factors relating to differences in the difficulty of making the various configurations. We knew that some of the configurations would be easier to make than others. For example, Ekman, Roper, and Hager (1980) had determined how well children of different ages could perform specific muscle movements and found that the muscle movements required for the sadness and fear configurations were more difficult to make (i.e., fewer children of any age, even with the benefit of a mirror, could make these movements) than the movements required for the anger configuration, with the movements required for the surprise, disgust, and happiness configurations being the easiest to make.

Our concern with configuration difficulty and heart rate change was not primarily with the metabolic demands associated with the number of *facial* muscles that had to be contracted. The facial muscles are relatively small in size and their contraction makes relatively minimal metabolic demands on the heart. For this reason, we would not expect moving facial muscles by itself to produce substantial cardiovascular changes. More worrisome were the rather large cardiovascular changes that can occur if subjects become frustrated[4] when trying to make the more difficult configurations, or if they begin to fidget and become tense. These strong emotions and increases in large muscle tonus could make sufficient metabolic demands on the heart to account for cardiovascular changes of the magnitude observed during the Directed Facial Action task.

Thus, we tried to minimize these risks: (a) studying only subjects who were skilled at contracting their facial muscles (actors originally, then carefully screened subjects); (b) discarding trials where subjects laughed or appeared to become embarrassed; (c) using a quality coding system that downgraded configurations that took longer than 60 s to make; (d) measuring concomitant muscle activity in several different ways; and, in some studies (e) obtaining difficulty ratings. We thought these precautions would enable us to reject the hypothesis that heart rate changes were mediated by configuration difficulty.

Nonetheless, Boiten concluded that differences in difficulty were responsible for the cardiac differences among the emotional configurations found in the Directed Facial Action task. He based this conclusion largely on the finding that the two most difficult configurations (fear and sadness) had faster heart rate than the less difficult ones (e.g., disgust and happiness). In contrast, we had concluded that difficulty was not a likely mediator because (a) cardiac differences did not exactly parallel the difficulty groupings (especially for anger and disgust, which were rated as equally difficult[5] but differed significantly in heart rate), and (b) we found no correlations between difficulty ratings and heart rate change within configurations (recall that Boiten only found one such correlation—for the anger configuration).

An analytic strategy is available to provide a formal test of the hypothesis that heart rate differences in the Directed Facial Action task are mediated by differences in configuration difficulty. However, neither Boiten nor we did this critical analysis.

Mediation of Heart Rate Change in the Directed Facial Action Task by Difficulty: The Missing Critical Analysis

There are three possible roles that configuration difficulty can play in accounting for the relationship between emotional facial configurations and heart rate change in the Directed Facial Action task: (a) The facial configurations do not differ in difficulty and thus difficulty cannot be responsible for found differences in heart

[4]Some support for this interpretation was derived from coding the initial open-ended responses of subjects following each trial (using data from Experiment 3 in Levenson et al., 1990) by assigning a value of 0 when frustration was not mentioned and a value of 1 when it was. Greater frustration was associated with longer time to make the face, $r(170) = .18$, $p < .02$. A similar relation with greater rated difficulty only approached significance, $r(176) = .13$, $p = .09$. Frustration was not correlated with general somatic activity, $r(171) = .01$, n.s.

[5]This point is easily lost in Boiten's paper. On page 127, he reported that the difference in effort ratings between anger and disgust was not significant. However, in other places he refers to anger as being more difficult than disgust.

rate, (b) the facial configurations differ in difficulty and *fully account* for found differences in heart rate, and (c) the facial configurations differ in difficulty but *cannot fully account* for found differences in heart rate.

Prior research (Ekman et al., 1980) as well as Boiten's and our findings using the Directed Facial Action task indicate that these emotional configurations clearly do differ in difficulty. This allows us to reject the first possible role for configuration difficulty postulated in the previous paragraph. As for the remaining two possibilities, there are several ways to approach the question of whether configuration difficulty can or cannot fully account for found heart rate changes, all of which involve determining whether emotional configurations produce significant differences in heart rate above and beyond those changes in heart rate attributable to difficulty.

Baron and Kenny (1986) described a formal procedure for establishing mediation effects. Applied to the issue at hand, this procedure would require establishing three things to conclude that difficulty mediates the heart rate differences among emotional configurations in the Directed Facial Action task: (a) Variations in emotional configuration account for variations in difficulty ratings, (b) variations in difficulty ratings account for variations in heart rate change, and (c) controlling for "a" and "b," variations in emotional configuration no longer account for variations in heart rate change. Unfortunately the Baron and Kenny approach is based on using multiple regression analyses, which become quite cumbersome when used with the kinds of within-subject designs (i.e., all subjects produce all emotional configurations) used by Boiten and by us (see Keppel & Zedeck, 1989). In addition, eliminating trials on which facial configurations fail to meet quality criteria creates missing data at some levels of the within-subject emotional configuration factor. Such within-subject missing data cause problems for many data analytic programs (e.g., SPSS typically drops the entire case from an analysis when any level of a within-subject factor is missing). For these reasons, it was not feasible to conduct the Baron and Kenny analyses using multiple regressions; however, we were able to use other statistical tests to conduct analyses that closely followed their logic for establishing mediation.

Analytic Strategy

Lacking access to Boiten's raw data, we made use of his published data to examine the extent to which his findings met the Baron and Kenny criteria for mediation. With our own data, we are able to conduct the more extensive analyses necessary for settling this controversy.

Possible Mediators

Boiten based his conclusions concerning difficulty on end-of-trial self-report ratings obtained from his subjects on a second set of trials that followed those on which the heart rate data were obtained. We had also obtained end-of-trial difficulty ratings (on the same trial as the heart rate data) in one of our studies (Experiment 3 in Levenson et al., 1990). These data enabled a direct test of mediation by difficulty measured by retrospective self-report.

In addition to this measure of difficulty, parallel analyses evaluated two other potentially relevant mediators of heart rate change: (a) the time it took subjects to produce the facial configuration on each trial, and (b) the amount of concomitant muscle activity on each trial. Unlike self-reported difficulty ratings, which we only obtained in one study, these other two measures were obtained in all three of the experiments reported in our 1990 paper. Moreover, these additional measures were arguably more "objective," having the advantage of being based on something other than subjects' retrospective judgments.

To measure the amount of time it took each participant to make each configuration, we timed the interval between the beginning of the instructions to make the facial configuration and the time when the coach told the participant to hold the face. Our logic for including this measure is that it should be directly reflective of difficulty—the less difficulty the participant encountered, the more quickly the configuration would be made. To provide some indication of concomitant muscle activity, we measured forearm flexor EMG in the first study and measured general somatic activity (obtained from a sensor under the participant's chair that was sensitive to bodily movement in any direction) in the other two studies. Our logic for including these muscle activity measures was to be sensitive to the extent to which heart rate differences between emotion trials could be explained in terms of concomitant muscle activity (e.g., squirming, tensing, fidgeting).

Because all three potential mediators were obtained in our Experiment 3 (Levenson et al., 1990), we were able to evaluate their correlations in that study. The correlation between subjects' difficulty ratings and the time it took to make the face was significant, $r = 0.69$, $p < .001$, and in the expected direction (i.e., the longer it took to make the face, the more difficulty the subject reported). This relation between our self-report measure of difficulty and a behavioral measure that should also reflect difficulty suggests good convergent validity. Measures of somatic activity, however, were not correlated with difficulty ratings, $r = -.06$, n.s., or with the time it took to make the face, $r = -.03$, n.s., suggesting that evaluating somatic activity might reveal an independent mediator of heart rate changes.

Testing three different potential mediators provides a very conservative test that increases the likelihood of rejecting our hypothesis that it is the emotions associated with the configurations that are responsible for found heart rate differences among them. Conversely, if the mediating roles of the three potential mediators were not supported, we would gain more confidence in our hypothesis. Table 1 provides the results of the mediational analyses.

Analysis 1: Does Emotional Configuration Predict the Potential Mediators?

We tested this by conducting an ANOVA on each potential mediator with emotional configuration as a within-subject factor. These analyses revealed that the effect of emotional configuration was significant for difficulty ratings, $F(5,70) = 42.08$, $p < .001$, significant for time to make configuration, $F(5,59) = 38.33$, $p < .001$, and significant for somatic activity, $F(5,60) = 2.80$, $p = .02$. Boiten reported a similar analysis that revealed significant differences in difficulty ratings, $F(5,10) = 5.68$, $p < .01$. Thus, all of the potential mediators proposed by us and by Boiten passed the first test posed by Baron and Kenny.

Analysis 2: Do the potential Mediators Predict Heart Rate Change?

We tested this using the average of the within-subject correlations between heart rate change and each of our potential mediators (using data from the six configurations for each subject in Experiment 3 in Levenson et al., 1990). The latter analysis revealed that none of the potential mediators predicted heart rate change (difficulty ratings: average $r(28) = .18$, n.s.; time to make configuration: average $r(27) = .23$, n.s.; somatic activity: $r(28) = -.13$, n.s.). Recall that in Boiten's within-subject analyses, the average correlation between effort ratings and heart rate was also not

Table 1. *Results of Mediation Analysis Following Baron and Kenny (1986)*

Research group: Potential mediator	I. Emotional configuration predicts mediator (Test: Significant emotion main effect in ANOVA of mediator)	II. Mediator predicts heart rate change (Test: Significant average correlation between mediator and heart rate change)	III. Emotion configuration still predicts heart rate change when controlling for mediator (Test: 1. Significant emotion main effect in ANOVA of residual heart rate (corrected for mediator) 2. Significant emotion main effect in ANCOVA of heart rate controlling for mediator 3. Nonsignificant reduction in idiographic hit rates when heart rate corrected for mediator)	Conclusion: Are heart rate differences among emotional configurations accounted for by mediator? (Test: Requires columns I and II to be "Yes" and column III to be "No")
Boiten: Difficulty	Yes	No	1. Not tested 2. Not tested 3. Not tested	No
Levenson et al.: Difficulty	Yes	No	1. Yes 2. Yes 3. Yes	No
Levenson et al.: Time to make face	Yes	No	1. Yes 2. Yes 3. Yes	No
Levenson et al.: Somatic activity	Yes	No	1. Yes 2. Yes 3. Yes	No

significant, $r(13) = .32$, n.s. Thus, all three of our mediators and Boiten's effort ratings failed the second test posed by Baron and Kenny.

Analysis 3: Does the Emotional Configuration Still Predict Heart Rate Change Even after Controlling for Potential Mediators?

This is arguably the most critical analysis because it directly tests whether the relationship between emotional configuration and heart rate change remains when the effects of the potential mediators are removed. Because of its critical nature, we evaluated this possibility in three different ways, the first using residual scores in an ANOVA, the second using the original (nonresidualized) scores in an analysis of covariance (ANCOVA), and the third using an idiographic analysis of "hit rates." The first two approaches are conceptually similar, but are computationally different and involve different sets of statistical assumptions. Thus, they provide a broader and arguably more robust test of the purported mediational relationships.

Residual heart rate. For the first analysis, we computed three sets of within-subject residual heart rate scores, each of which represented heart rate change corrected for one of the potential mediators. These corrections are representative of the regression-based approach often used by psychophysiologists to remove the effects of a "nuisance" factor from the primary physiological measure of interest (e.g., the computation of "additional heart rate" corrected for minute ventilation in Wilhelm & Roth, 1998). Specifically, for each subject, we calculated residual heart rate as the measured heart rate minus the predicted heart rate. Predicted scores for each subject were derived from a linear regression analysis conducted using data from the six emotion configuration trials in which heart rate change was the dependent variable and one of the potential mediators was the predictor variable. The resultant residual scores (only using configurations meeting our quality criterion) were analyzed by ANOVA (using an unweighted means solution to handle missing data) to determine if there was a significant main effect for emotional configuration. Results indicated that the emotion configuration main effect was still significant for heart rate when corrected for difficulty ratings, $F(5,66) = 2.48$, $p = .04$; for heart rate corrected for the time it took to make the configuration, $F(5,141) = 7.28$, $p < .001$; and for heart rate data corrected for somatic activity, $F(5,146) = 10.96$, $p < .001$. Thus, using the residual heart rate data (which removed the variance associated with a potential mediator), substantial effects for emotion configuration still remained. For this reason, we conclude that none of the three potential mediators passed the third test posed by Baron and Kenny to establish mediation.

Analysis of covariance. For the second analysis, the potential mediators served as covariates in ANCOVAs performed using SAS PROC Mixed on the original (i.e., nonresidualized) scores with emotional configuration as a within-subject factor. Because of computational problems that missing data produce in ANCOVAs with repeated measures, we had to include all configurations in these analyses regardless of whether they met our quality criterion (thus we conducted this particular set of analyses in the same manner as Boiten conducted all of his, i.e., without regard to configuration quality). Results indicated that with both the covariate (i.e., rated difficulty) and emotional configuration effects adjusted for each other, in the final model the main effect for emotional configuration was still significant, $F(5,28) = 3.37$, $p = .02$, but the effects of the difficulty covariate were not, $F(1,28) = 0.28$, n.s. For the time to make the configuration, in the final model, the main effect for emotion configuration was significant, $F(5,59) = 8.40$, $p < .001$, but the effects of the time to make the configuration covariate was not, $F(1,59) = 0.50$, n.s. For somatic activity, in the final model, the main effect for emotion configuration was significant, $F(5,60) = 8.06$, $p < .001$, as were the effects of the somatic activity covariate, $F(1,60) = 8.76$, $p = .004$.

Thus, using the ANCOVA approach, none of the three potential mediators passed the third test posed by Baron and Kenny, insofar as none caused the main effect for emotion configuration to become nonsignificant. Further, only in the case of somatic activity did a potential mediator account for significant variance in the final model. This latter finding is consistent with our argument presented earlier that, in terms of metabolic demands on the heart, the activity of the large nonfacial muscles (indexed by somatic activity) is likely much more important than the activity of the small facial muscles (indexed by difficulty ratings and by the time needed to produce the configuration) in understanding the heart rate changes produced in the Directed Facial Action task. Nonetheless, even with the powerful cardiac–somatic relation (e.g., Obrist, 1981) controlled for, the heart rate differences between emotional configurations remained significant.

Idiographic analyses. The preceding analyses of residualized heart rate and covariance closely follow the logic of the third test for mediation proposed by Baron and Kenny, establishing that there is a significant relationship between emotional configuration and heart rate change even when controlling for three potential mediators. This approach, however, does not tell us whether the "pattern" of associated heart rate across the configurations is changed when the mediators are controlled. Stated differently, these analyses tell us that there are still significant differences in heart rate among configurations but not whether anger, fear, and sadness configurations still have faster heart rate than disgust configurations. To test this possibility, we conducted the kinds of idiographic analyses of "hit rates" that we had used in our 1990 paper, examining whether individual subjects evidenced the five differences among pairs of emotional configurations that we had originally found in group data. Thus we determined for each subject whether heart rate was faster (a) during anger than during disgust, (b) during fear than disgust, (c) during sadness than disgust, (d) during anger than happiness, and (e) during fear than happiness. For each subject, if both configurations in a comparison met our quality criteria, we then compared the attendant heart rate. If the heart rate data were in the indicated direction, it was counted as a hit; if they were equal or in the opposite direction, it was counted as a miss.

For each of the three potential mediators, we first computed these hit rates using the uncorrected heart rate data and then again using the residualized heart rate data (as before, corrected within-subject for one potential mediator). A statistical test was then applied to determine if the hit rate was decreased significantly when the mediator was considered. For the one study in which difficulty ratings were obtained, the hit rate using the uncorrected heart rate data was 56.4%. The hit rate was also 56.4% when corrected for difficulty (change not significant, $z = .00$). For the three studies in which time to make the configuration and somatic activity were measured, the hit rate using the uncorrected heart rate data was 69.4%. The hit rate was 64.2% when corrected for time to make the face (change not significant, $z = -.81$) and 64.5% when corrected for somatic activity (change not significant, $z = -.76$). Thus, applying these idiographic tests, the extent to which this set of five heart rate differences among emotional configurations was found was not significantly affected by controlling for the three possible mediators.

Discussion

Boiten (1996) provided a close methodological replication of our studies using the Directed Facial Action task (Ekman et al., 1983; Levenson et al., 1990, 1991, 1992) and found virtually identical heart rate differences, highly similar self-reports of experienced emotion, and highly similar self-reports of reported difficulty associated with six emotional configurations. Boiten attributed the heart rate differences he found to differences in the effort involved in making the six configurations as indexed by subjects' self-reports of difficulty. Considering essentially identical findings from our work, we had concluded that difficulty was not a likely mediator of found heart rate differences among the configurations. However, neither research group had conducted the critical mediational analyses necessary to determine whether differences in difficulty were sufficient to account for the heart rate changes that were found.

Rejecting the Alternative Mediational Hypotheses

Results of these mediational analyses presented in the present paper reveal that, in our studies, heart rate differences among emotional configurations in the Directed Facial Action task cannot be accounted for by self-reported difficulty, or by two other potential mediators of heart rate change (i.e., the time it takes subjects to make the configurations or the amount of concomitant muscle activity). All three potential mediators from our studies (as well as Boiten's difficulty ratings) fail to pass Baron and Kenny's (1986) second test for mediation (i.e., mediator correlated with heart rate change). And most importantly, all three potential mediators from our studies also fail to pass Baron and Kenny's third test for mediation (i.e., controlling for mediator eliminates significant differences in heart rate for the different emotional configurations) regardless of whether this is assessed using residual heart rate scores (corrected for the potential mediators), analysis of covariance, or idiographic analyses of hit rates.

Taken together, these analyses provide a firm basis for rejecting the alternative hypotheses that heart rate differences among emotions in the Directed Facial Action task are mediated by differences in configuration difficulty, by the time it takes to make the configurations, or by the kinds of concomitant muscle activity we measured. Admittedly, applying the Baron and Kenny mediation model to these kinds of within-subject data (which are analogous to those commonly collected in psychophysiological studies of emotion), requires some stretching. However, we tried to compensate for this by using a strict .05 alpha level for their third test and by increasing the number of opportunities for the alternative mediational hypothesis to be supported, testing each of three different potential mediators using three different statistical approaches (all of which supported rejecting the alternative hypotheses).

Emotion, Autonomic Specificity, and Motion

Viewed in the larger context of research on the nature of emotion, these findings surely do not settle the enduring question of whether there are autonomic differences among emotions. The use of the

Directed Facial Action task to address this question has its limitations and has not been without controversy. Clearly, emotions are not typically elicited by voluntarily making facial expressions, just as they are not typically initiated by an injection of adrenaline (e.g., Schachter & Singer, 1962). Nevertheless, both of these novel approaches have revealed (and hopefully will continue to reveal) interesting things about the nature of emotion.

In claiming that heart rate changes found in the Directed Facial Action task cannot be fully accounted for using these particular somatic measures, we are not implying that cardiovascular changes in emotion are independent of somatic (and respiratory) changes. Rather, we believe that cardiovascular changes in emotion are part of an organized multisystem response in which the appropriate physiological support is provided for prototypical behavioral responses associated with certain emotions (e.g., fighting associated with anger). Somatic activation plays a critical role in many of these behavioral responses[6] and cardiovascular and respiratory activation play critical roles in providing the necessary physiological support. Thus, we would expect cardiovascular responses in emotion to be highly integrated with the action of somatic, respiratory, and other biological systems (e.g., Levenson, in press). The primary point of the present paper is not that cardiovascular changes are independent of somatic changes in emotion but rather that cardiovascular changes during the Directed Facial Action task cannot be explained as being merely epiphenomena of the effort expanded in contracting facial muscles.

The mechanism by which the Directed Facial Action task produces the cardiac changes that we and Boiten have found (as well as the peripheral changes in temperature and vascular activity that we have found in our previous studies) are still unclear. We have hypothesized on theoretical grounds (Ekman et al., 1983) that this derives from the *emotional* characteristics of the configurations. This assertion is supported by several findings from our empirical work (Levenson et al., 1990) using the Directed Facial Action task: (a) Autonomic differences are most pronounced when configurations most closely resemble the associated emotional expressions, (b) autonomic differences are most pronounced when subjects report experiencing the associated emotion, and (c) subjects report experiencing the associated emotion most strongly when configurations most closely resemble the associated emotional expressions. These findings, of course, are far from definitive, and thus it will continue to be important to evaluate viable alternative hypotheses.

[6] As Levenson and others have noted elsewhere (e.g., Levenson, 1992, in press), explaining autonomic differences among emotions exclusively on the basis of associated prototypical behavioral responses is not without problems. For example, emotions may have more than one associated behavioral response, each of which could produce different metabolic demands (e.g., fleeing and freezing in fear; agitated distress and vegetative inactivity in sadness). These issues fall outside of the particular focus of the present paper, but loom as important questions for future work.

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(RECEIVED April 6, 2000; Accepted DECEMBER 4, 2001)