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TESTING CONTRAST AVOIDANCE MODEL USING A COMPUTER-BASED ANALYSIS OF EMOTIONAL FACIAL EXPRESSIONS

A Dissertation in

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ABSTRACT

Recent studies suggest that contrast avoidance may function in both worry and rumination. However, the mechanism of contrast avoidance in worry and rumination has only been tested for subjective and physiological experience. Although facial expression is another strong indicator of one's affective experience, emotional contrast avoidance has never been tested in this regard, and only a few studies have attempted to assess facial expression in the processes of worry and rumination. Advances in computer technology allow a more accurate measurement of facial expression. Using FaceReader, which was developed based on machine learning in artificial neural networks, we tested whether the emotional contrast avoidance phenomenon was found in the processes of worry and rumination. In addition, we also attempted to test whether relaxation enhanced positive emotional contrast. Results showed that sad facial expression in response to rumination supported a Contrast Avoidance Model. Findings of the current study are expected to contribute to better understanding of the underlying mechanism of repetitive negative thought.

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ADKNOWLEDGEMENTS

This dissertation is dedicated to the blessed memory of my mother, Seok-Hee Seo, who was a great therapist and my inspiration to pursue a doctoral degree in Clinical Psychology. Although she was unable to see my graduation, she is still living in my heart and we will always be together.

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Chapter 1. Introduction

Across the ages and around the world, repetitive negative thought (also known as perseverative thought) has been recognized as a cause of various mental health problems. Studies have shown that repetitive negative thought may increase pathological symptoms and associated behavioral problems (Calmes & Roberts, 2007; Fresco, Frankel, Mennin, Turk, & Heimberg, 2002; Muris, Roelofs, Rassin, Franken, & Mayer, 2005). Therefore, it is important to understand the mechanisms behind such thoughts.

Worry and rumination have been the two most widely studied repetitive negative thoughts. However, these thought processes have been examined within two different disorders. Worry has been considered the cardinal feature of generalized anxiety disorder (GAD). On the other hand, rumination has been studied predominantly in the context of major depressive disorder (MDD) (Nolen-Hoeksema, Wisco, & Lyubomirsky, 2008). One of the reasons the two constructs have been studied within the two distinct traditions might have been due to their different definitions. Worry has been defined as a chain of uncontrollable thoughts about future events whose outcome is anticipated to be negative (Borkovec, Robinson, Pruzinsky, & DePree, 1983). Rumination was originally defined as a chain of thoughts focusing on depressive symptoms and their negative implications (Nolen-Hoeksema, 1991). Although the temporal orientation of rumination was not specified in the original definition, in later studies, a group of researchers suggested that the temporal focus of rumination may be primarily about the past (Brosschot, Gerin, & Thayer, 2006; Nolen-Hoeksema et al., 2008; Watkins, Moulds, & Mackintosh, 2005).

On the other hand, a growing number of empirical studies have provided evidence for their similarities. For example, Segerstrom, Tsao, Alden, and Craske (2000) found that worry and rumination were strongly correlated with each other among both clinical and non-clinical samples. They found that worry and rumination were included under the same latent variable and this umbrella variable was positively correlated with both anxiety and depression. Additional evidence also has shown that worry and rumination were indistinguishably associated with symptoms of anxiety and depression. For instance, Fresco et al. (2002) conducted a factor analysis of self-report measures of worry and rumination and found that factors of worry and rumination were equally correlated with both anxiety and depression.

The overlap between worry and rumination created a need to reconcile the two different traditions of study and improve upon our understanding of their underlying mechanisms. Although previous studies attempted to clarify overlapping and distinct characteristics of worry and rumination with respect to their interconnectedness to anxiety and depression, they focused primarily on symptomatologic aspects, and thus were not enough to explain the common foundation underlying them. Until now, only a handful of studies have attempted to reconcile the disparities between theories and evidence of worry and rumination by providing a more comprehensive explanation of the two repetitive thought styles (Aldao, Mennin, & McLaughlin, 2013; Kim & Newman, 2016).

Based on early experimental findings showing that worry enabled decreased initial reactivity to fearful images (Borkovec & Hu, 1990; Borkovec, Alcaine, & Behar, 2004), several researchers suggested that worry may allow avoidance of negative emotional experience (Mennin, Heimberg, Turk, & Fresco, 2005; Newman, Castonguay, Borkovec, & Molnar, 2004; Roemer, Salters, Raffa, & Orsillo, 2005). However, there have been ample studies showing contradicting evidence. A group of previous studies demonstrated that worry actually facilitates experience of increased levels of negative emotion and heightened somatic responses rather than allowing avoidance of those (Andor, Gerlach, & Rist, 2008; Borkovec & Costello, 1993; Borkovec & Inz, 1990; Brosschot, Van Dijk, & Thayer, 2007; Llera & Newman, 2010; Pieper, Brosschot, van der Leeden, & Thayer, 2007; Stapinski, Abbott, & Rapee, 2010).

One of the criticisms suggested regarding the limitation of the emotional avoidance theory is that it does not consider worry as part of a negative emotional process, but it focuses on subsequent reactivity to negative emotional exposure (Llera & Newman, 2010; Newman & Llera, 2011). Based on the idea that the emotional experience during worry and post negative emotional exposure involve distinct emotion processes, Llera and Newman (2010) conducted a laboratory study assessing emotional and somatic changes. They found that negative emotionality and somatic responses were actually heightened by worry, and they were sustained during subsequent exposure to negative emotion inducing film clips, regardless of the diagnostic groups (i.e., GAD group and healthy controls). These findings led Newman and Llera (2011) to suggest a new model of worry. By synthesizing confounding evidence from previous studies, Contrast Avoidance Model (CAM) proposes that as a way of decreasing emotional shock from a sudden increase in negative emotion, people actively adopt worry as an anticipatory coping strategy (Newman & Llera, 2011).

A series of studies showed supporting evidence. A laboratory study tested this model by differentiating subjective and somatic emotional experience from baseline to induction and induction to emotional exposure and found evidence supporting CAM (Llera & Newman, 2014). They found that worry increased negative emotions, and these negative emotions attenuated a subsequent increase in negative emotion (i.e., avoidance of negative contrast). On the other hand, they found that relaxation decreased negative emotions, and such a decrease enhanced a subsequent increase in negative emotion. Interestingly, individuals with GAD presented a significant preference for worry in preventing a negative contrast, when it was assessed by a subjective report measure. This indicates that the perception of the utility of worry might differ across diagnostic groups. Another experimental study used a speech task as an emotional exposure and found consistent results supporting the main hypotheses of the model (Skodzik, Zettler, Topper, Blechert, & Ehring, 2016). Similar to the previous laboratory study (Llera &

Newman, 2014), this study assessed subjective responding and physiological reactivity of college samples across baseline, induction and exposure. Unlike the notion of the emotional avoidance model, worry gave rise to increased negative affect and physiological arousal. In addition, worry also contributed to the attenuation of further increase during the speech task. Other supportive evidence was also found in a neuroimaging study. Researchers tested neural and physiological correlates of worry and found that a worry induction increased startle response and Blood Oxygen-level Dependent (BOLD) reactivity rather than decreasing them (Steinfurth, Alius, Wendt, & Hamm, 2017). These findings contradict the suggestions of the emotional avoidance hypothesis (e.g., worry enhances the attenuation of negative affect).

Recent studies also attempted to examine contrast avoidance within non-laboratory contexts. One study conducted momentary assessment using smartphones, and found that longer worry duration, heightened negative thought valence and uncontrollability of thoughts predicted greater levels of sustained arousal. In addition, increased negative thought valence and uncontrollability also predicted the avoidance of a negative contrast in the next hour. These results provide ecologically valid evidence supporting the CAM (Newman et al., 2019). Moreover, a longitudinal study assessed weekly emotional experience by asking participants to describe their "worst event of the past week" and examined how much the worst event involved negative emotional contrast (Crouch, Lewis, Erickson, & Newman, 2017). In the study, higher baseline GAD symptoms predicted greater weekly experience of negative emotion even when the covariance of depression symptoms was accounted for. The increased weekly experience of negativity conflicted with the notion of the emotional avoidance model making the model less convincing. Furthermore, results from a recent measure validation study also showed evidence supporting CAM. In the measure validation study, two measures were developed to assess the contrast avoidance process (Llera & Newman, 2017). One measure focused on the use of worry in relation to contrast avoidance and the other measure focused on general emotional mechanisms of contrast avoidance (i.e., intentionally creating and sustaining negative emotion). In the study, scores on both measures were significantly higher in a GAD group than in non-anxious controls. Furthermore, results of the construct validity analysis showed that those with clinical levels of GAD were more likely to present greater discomfort with a negative emotional contrast, greater preference for feeling negative as a means to avoid those negative contrasts, and preference for expecting the worse as opposed to hoping for the best. Note that this type of group difference was found only at the perceptual level in the previous study comparing the perceived utility of worry among different diagnostic groups. In the study, there was no significant group difference in the experimental assessment of contrast avoidance (Llera & Newman, 2014).

At the same time, some evidence has suggested that CAM may also function in rumination. Previous studies have demonstrated that not only individuals with GAD but also people with MDD report more positive beliefs about rumination (Papageorgiou & Wells, 2003; Watkins et al., 2005; Watkins & Moulds, 2005). Furthermore, consistent with the hypotheses of CAM, rumination was associated with increased dysphoric mood (McLaughlin, Borkovec, & Sibrava, 2007; Nolen-Hoeksema & Morrow, 1993) and decreased positive affect (McLaughlin, Borkovec, et al., 2007). Moreover, rumination was positively correlated with prolonged negative affect in daily life (Moberly & Watkins, 2008). Based on this evidence, Kim and Newman (2016) suggested that emotional contrast avoidance may be a transdiagnostic mechanism that operates not only in worry but also in rumination, but that the content of the two repetitive thought types differ from each other. In their experimental study, they found that worry increased fear from baseline and sustained this fear during subsequent exposure to a fearful video clip. Unlike worry, rumination was associated with sadness. These results indicated that worry and rumination may have a similar mechanism (i.e., emotional contrast) but that the content of emotions which activate this mechanism might differ from each other.

However, this hypothesis has been tested only within the context of subjective and physiological emotional experience. Furthermore, although there has been growing demand for objective assessment of emotions, it has received little attention in the study of worry and rumination. Among various types of affective cues, facial expression has long been considered one of the most powerful indicators of one's affective state (Russell & Fernández-Dols, 1997). Although there has been significant progress in understanding human facial expression starting with early attempts at analyzing facial musculature (Duchenne de Bologne, 1990) and categorizing different human facial expressions (Ekman & Friesen, 1971; Plutchik, 1980), during the past four decades, assessment of facial expression has relied on observers' ability to correctly infer the emotion. However, one of the criticisms of this method is that subjective ratings of facial expressions are not always reliable. For example, previous studies have shown that decoding accuracy of human raters is largely affected by the intensity of emotional facial expressions and observers are not good at detecting subtle or neutral facial expressions (Hess, Blairy, & Kleck, 1997; Lewinski, den Uyl, & Butler, 2014; Nowicki Jr & Carton, 1993). In addition, perception of facial expressions can be largely influenced by the observer's demographic characteristics, such as gender (Hall & Matsumoto, 2004; Rotter & Rotter, 1988) and age (Calder et al., 2003; Suzuki, Hoshino, Shigemasu, & Kawamura, 2007). In experimental studies, these limitations may be even more critical given that researchers could not always secure enough observers to ensure that their ratings were equivalent to normative ratings. Therefore, variations in human ratings are unavoidable. In addition, although a massive number of observers can be recruited, collection and analysis of data would require extreme amounts of effort and time. Fortunately, improvements in computer technology has made it more feasible to accurately decode facial expressions.

One of the most successful automated facial coding (AFC) systems is software developed based on deep learning in artificial neural networks (i.e., machine learning). Although there have been several computerized AFC systems, FaceReader has been the most widely used commercially available AFC software. Using a machine learning algorithm, FaceReader can accurately identify facial expressions more efficiently than human observers. Particularly, in decoding subtle facial expressions, FaceReader outperforms human raters. Previous studies have shown that FaceReader can decode neutral facial expressions almost three times better than human raters (Lewinski, 2015). Therefore, application of this novel method could greatly contribute to accurate analysis of facial expressions and allow more objective understanding of the contrast avoidance in worry and rumination.

To date, an extremely small number of studies have examined facial expressions in relation to worry and rumination, and none of the previous studies have systematically compared the two repetitive thought processes together. Only one study looked at worry and examined individuals' judgment of emotion from facial expression in response to images. However, the study did not look at facial expression during worry but only considered worry as one of the emotional labels given to different facial images. Along with confusion and concentration, worry was one of the three most frequent emotion descriptors reported for images with various facial expressions (Rozin & Cohen, 2003). Only a handful of studies examined facial expression in relation to rumination. However, similar to the previous worry study, none of them analyzed facial expressions during the process of rumination. Rather, these studies focused primarily on the effects of rumination on perceptual biases in detecting negative facial expressions (Hooker, Gyurak, Verosky, Miyakawa, & Ayduk, 2010; Raes, Hermans, & Williams, 2006; Vervoort et al., 2007).

Although the majority of studies focused on attentional bias of individuals with anxiety or depression, there have been a handful of attempts to analyze facial expressions as non-verbal reactions to different types of stressors. For example, in a study that compared differences among individuals with high anxiety, low anxiety, and high repression in facial expression (Asendorpf & Scherer, 1983), high anxiety participants exhibited significantly greater facial anxiety than the other two groups. In addition, Wallbott and Scherer (1991) administered stress-arousing tasks to high anxiety subjects, low anxiety subjects, and anxiety deniers and measured their facial expressions along with their subjective feelings and autonomic arousal. Anxiety-denying male participants exhibited a higher total amount of facial activity and higher frequency of smiling while they were engaging in the high-emotional condition. Furthermore, anxiety deniers exhibited more frequent jaw dropping during high-stress conditions. In another study, researchers assessed affective processes of GAD participants and non-anxious controls using a disclosure task. Two raters coded each participants' affective displays of happiness/joy, sadness, anger and tension/anxiety based on facial expressions and other behavioral cues, while they were disclosing their personal information to a confederate. Results of the study indicated that GAD participants exhibited greater sadness than controls during the disclosure tasks, particularly after the confederate's disclosures of guilt, dissatisfaction and regret in various interpersonal scenarios (Erickson & Newman, 2007). On the other hand, Schwartz, Fair, Salt, Mandel, and Klerman (1976) recruited depressed and normal subjects and assessed their electromyographic (EMG) patterns while they were engaging in happy or sad imagery. They found that the difference between depressed and non-depressed controls in EKG response became magnified when they were engaging in happy imagery task. Furthermore, in a study that compared facial expression between depressed patients and non-depressed controls, Gehricke and Shapiro (2000) found that depressed patients showed reduced facial muscle activity regardless of social contexts. In other studies, depressed patients exhibited impairments in producing positive facial expressions (Rubinow & Post, 1992; Sloan, Strauss, & Wisner, 2001), particularly when reacting to positive stimuli (Berenbaum & Oltmanns, 1992).

Considering the limited number of studies, investigating facial expression during and after worry and rumination would be an important contribution, not only to the test of contrast avoidance but also to better understand similarities and differences between the two perseverative processes. In the current study, we aimed to examine contrast avoidance processes of worry and rumination by assessing changes in emotional facial expression. In order to test this, we adopted experimental methods used in a previous study, which examined the changes in different emotions from baseline to induction and induction to video exposure phases (Llera & Newman, 2014). However, there was a methodological issue that we had to consider. Unlike resting baseline and video exposure phases wherein participants were allowed to open their eyes, participants were asked to close their eyes while they were engaging with induction tasks (i.e., in the current study, worry, rumination and relaxation). We judged that this difference (i.e., closing eyes) might limit the manifestation of facial expressions during the induction phase. Therefore, in testing our hypotheses, we leveraged the comparison between different trends in response to different induction tasks (e.g. worry slope vs. relaxation slope), rather than comparing the absolute amount of changes in the intensity of emotional facial expressions (e.g., how much negative facial expression became intensified due to the function of worry). Furthermore, we attempted to test whether relaxation, in comparison of worry and rumination enhanced negative contrast.

We proposed five hypotheses. First, consistent with previous findings on subjective and physiological responses (Kim & Newman, 2016; Llera & Newman, 2014), worry would yield a relatively greater increase in fear facial expression than relaxation (note that in the previous study, worry facilitated contrast avoidance of fear, and rumination enhanced contrast avoidance of sadness). In addition, compared to relaxation, worry would lead to a relatively smaller increase in fear facial expression during the subsequent fear video exposure (hypothesis 1: avoidance of fear contrast in worry). Second, rumination would yield a relatively greater increase in sad facial expression than relaxation. Furthermore, rumination would cause a relatively smaller increase in sad facial expression during the sad video exposure (hypothesis 2: avoidance of sad contrast in rumination). Third, compared to worry and rumination, relaxation would lead to a decrease in negative facial expressions (i.e., fear and sad facial expressions). Also, this decrease would yield a sharp increase in negative facial expressions during the negative video exposures (hypothesis 3: contrast enhancement of negative emotions in relaxation). Forth, worry and rumination would yield a decrease in amusement facial expression and this would lead to an increase in amusement facial expression in response to the amusement video exposure (hypothesis 4: contrast enhancement of amusement in worry and rumination). Fifth, unlike worry and rumination, relaxation would not make any significant changes in amusement facial expression, and consequently, this would lead to a relatively sharper increase during the amusement video exposure (hypothesis 5: less effective contrast enhancement of amusement in relaxation). Although we anticipated that these processes would come out as a transdiagnostic phenomenon, similar to the findings from Llera and Newman (2014) and Kim and Newman (2016), we included diagnostic group in our statistical analysis in order to test this idea.

Chapter 2. Methods

Study Design

The current study had a three by three factorial design. Participants in each of the three groups (GAD group, MDD group, and Non-GAD/MDD controls) engaged with one of the three induction tasks (worry, rumination or relaxation) and they repeated this process three times until they watched all three emotion-inducing video clips (happy, fear and sad). Participant assignment to study conditions and the order of video presentation was fully counterbalanced.

Participants

For the current study, 239 undergraduate students taking introductory psychology classes were recruited from a student subject pool of a state university located in a semi-rural area. For their participation, two research credits were provided as partial course requirements. Participants were screened using their scores on the two psychological measures: the GAD-Q-IV and BDI-II. After screening, participants were assigned to one of the three groups. Those who met diagnostic criteria for generalized anxiety disorder (GAD) on the GAD-Q-IV, but were lower than 14 on the BDI-II were included. Those in the depression group were participants whose BDI-II scores were higher than 29, but below the diagnostic cutoff of the GAD-Q-IV. For the non-GAD and MDD control group, we assigned participants who did not meet the diagnostic cut-off on the GAD-Q-IV and whose scores were lower than 14 in the BDI-II. Participants' descriptive statistics are presented in the results section.

Screening Measures

Generalized Anxiety Disorder Questionnaire for DSM-IV (GAD-Q-IV)

The GAD-Q-IV is a diagnostic measure developed by Newman et al. (2002). The measure consists of nine self-report items which assess the existence and severity of GAD symptoms, as listed in the DSM-IV. Among the existing GAD measures, the GAD-Q-IV offers the most comprehensive assessment of GAD symptoms (Rodebaugh, Holaway, & Heimberg, 2008). The GAD-Q-IV has demonstrated very robust psychometric properties. In a previous measure validation study, the GAD-Q-IV indicated high retest reliability over a 2-week period (χ^2=42.1, κ = .64). When applying a cut-off score of 5.7, 92% of the sample carried the same diagnostic categorization over two weeks. Furthermore, the GAD-Q-IV demonstrated higher correlations with convergent measures (i.e., PSWQ, r = .55; RRAQ, r = .58) than discriminant measures (i.e., PDSS, r = .30; SDS, r = .26). Post hoc tests also indicated good interrater agreement with the ADIS-IV (Di Nardo, Brown, & Barlow, 1994) diagnostic interview (κ = .67, 88% correct classification of clinical GAD). A follow up validation study conducted on a clinical sample also showed high specificity (90-94.3%) and sensitivity (66-100%) (Moore, Anderson, Barnes, Haigh, & Fresco, 2014). Furthermore, this measure demonstrated good sensitivity in capturing changes as a result of treatment (Andersson et al., 2012; Paxling et al., 2011).

Beck Depression Inventory II (BDI-II)

The BDI-II is the revised edition of the BDI, developed by Beck, Steer, and Brown (1996). It is composed of 21 self-report questions intended to measure the presence and severity of depressive symptoms. In response to the revisions made in the DSM-IV, there were several changes made to the BDI-II. Unlike the original version, items of the BDI-II were designed to identify clinical level symptoms. Labels of items such as body image, hypochondriasis and work difficulty were reworded. Furthermore, unlike the BDI which measures depressive symptoms over a one-week timeframe, the BDI-II asks individuals to respond based on their experiences over a two-week time period. Ample numbers of studies have provided good support for its reliability and validity across diverse population samples. Psychometric properties among a clinical population indicate good reliability and validity. According to a recent comprehensive (Wang & Gorenstein, 2013), internal consistency was strong (Cronbach's α = 0.83-0.96). In addition, the retest reliability of the measure showed good to excellent stability over a two-week time period (Pearson's r = 0.73 – 0.96). In addition, the BDI-II had high correlations with the original BDI (Pearson's r = 0.82-0.94) and sufficient correlations with various depression measures (Pearson's r = 0.57-0.84). In regard to discriminant validity, the BDI-II had low correlations with scales that assessed alcohol (Pearson's r = 0.17-0.33) and drug abuse (Pearson's r = 0.26) and chronic pain (Pearson's r = 0.32). The BDI-II also had good criterion validity with a sensitivity over 70%. Furthermore, on a ROC curve, diagnostic accuracy was over 75%.

Experimental Tasks

Induction Tasks

For the induction of worry, rumination, and relaxation, we used the same experimental design as previous studies (Kim & Newman, 2016; Llera & Newman, 2014). For these studies, two different methods were used for the induction of worry and rumination. The most widely used method for the induction of worry is the experimental task developed by Borkovec and Inz (1990). This method asks participants to think about personally relevant events about which they were most worried. However, unlike the worry induction which relies on a self-guided process, for rumination induction, researchers typically administer a list of ruminative topics developed by Morrow and Nolen-Hoeksema (1990). In order to control effects from the two different induction methods, we standardized the format using a self-guided method (Kim & Newman, 2016). For the relaxation induction, we played a guided instruction for diaphragmatic breathing and progressive muscle relaxation. These instructions were developed by Kim and Newman (2016) and recorded by a professional voice artist with relaxing background music. Results of a pilot test showed that all three induction tasks successfully increased their target emotionality more so than other types of affect, worry, $F(2, 570) = 110.11$, $p < .001$, $\eta p^2 = .11$; rumination, $F(2, 570) = 137.32$, $p < .001$, $\eta p^2 = .14$; relaxation, $F(2, 570) = 104.90$, $p < .001$, $\eta p^2 = .11$ (Kim & Newman, 2016).

Video Exposure Stimuli

In order to induce fear, sadness, and amusement, we used a set of standardized video clips developed for emotion elicitation (Gross & Levenson, 1995). These film clips have been well-validated in numerous prior emotion studies (e.g., Cribb, Moulds, & Carter, 2006; McLaughlin, Mennin, & Farach, 2007; Wisco & Nolen-Hoeksema, 2009). For the elicitation of fear, participants watched a scary scene from “The Shining” for 82 seconds (Kubrick, 1980). For sadness, a clip from “The Champ” was presented to participants for 171 seconds, in which a boy cries at his father’s death (Lovell & Zeffirelli, 1979). In order to induce a sense of amusement, we played a fake orgasm scene from “When Harry Met Sally” for 155 seconds (Reiner, 1989).

Distraction Stimuli

At the end of each trial, we showed a set of validated video clips in order to wash out any affect induced by the emotion-eliciting stimuli. For this, a set of scenes from the documentary film, “Alaska’s Wild Denali” was played for 80 seconds (Hardesty, 1997). These film clips were also developed and validated by Gross and Levenson (1995).

Manipulation Check Measures

Induction Manipulation Check Measure

In order to ensure that each induction task produced significant levels of the targeted affect, we administered manipulation checks at the end of each induction task. These measures were composed of three 9-point Likert scale questions asking participants their levels of worry, rumination, and relaxation during induction tasks. This manipulation measure was adapted from the measure used by Llera and Newman (2014).

Video Exposure Manipulation Check Measure

For the manipulation check of video exposures, we administered a series of questions asking participants to rate their levels of fear, sadness, and amusement. For these questions, a 9-point Likert scale was used. This measure was adapted from questions used in the stimuli validation study (Gross & Levenson, 1995).

Emotional Facial Expression Measurement

For the acquisition of emotional facial expression data, we video recorded participants' facial displays throughout the experimental process, and we decoded the data using FaceReader 6.1, the 6th version of the automated facial expression recognition system (Noldus., 2014). The average accuracy of FaceReader in recognizing facial expressions from facial images has been reported as 88-89%, whereas human raters identified 85% of the images while spending much more time (Den Uyl & Van Kuilenburg, 2005; Lewinski et al., 2014). When recognizing neutral facial expressions, the accuracy of FaceReader was 90% outperforming the accuracy of human raters by 31% (Lewinski, 2015). Using an algorithm developed based on the Active Appearance Model (Cootes & Taylor, 2004), FaceReader 6.1 detected 500 facial landmark points in an image. These landmark points create a virtual mask which consists of three layers of wires. Next, an artificial neural network which learned classification of facial expressions through more than 10,000 of images identifies six basic emotions from the image. This classification is based on the Facial Action Coding system (Ekman & Friesen, 1978). In the current study, only lower face action units (AU) were used due to concerns related to our use of a different experimental protocol for the induction versus the video exposure (i.e., closing eyes while engaging with worry, rumination, and relaxation tasks). Based on the instructions of the Facial Action Coding System (Ekman, 1997), a composite score of lip stretcher (AU20) and jaw drop (AU26) was calculated for a fear facial expression. For a sad facial expression, we used a composite score of lip corner depressor (AU15) and chin raiser (AU17). We coded lip corner puller (AU12) for an amusement facial expression. For statistical analyses, the maximum values of facial expressions from each respective phase were used.

Procedure

At the beginning of the experiment, participants were given a consent form explaining the objectives, procedures, safety of the current study, and confidentiality of participants' responses.

For video recording, we obtained a separate consent from participants. Participation was voluntary and participants were able to leave the study anytime if they experienced any discomfort. No participants reported discomfort or discontinued the study. For de-identification of participants' information, we assigned a randomly generated four-digit number to each participant's material.

After consenting, participants were seated before a computer monitor which had a high-resolution webcam mounted on it. All instructions, stimuli, and emotion measures of the current study were programmed using E-prime (Psychology Software Tools Inc., 2002) and were presented via computer monitor (i.e., 23 inch computer monitor with 1,920 × 1,080 pixels). The experiment began with the baseline phase asking participants to sit for five minutes until they became acclimated to the experimental environment. After the baseline, they completed an emotion measure which consisted of a series of questions asking about their current emotionality. Next, investigators (i.e., undergraduate research assistants) trained participants with one of the three self-administered induction tasks based on their experimental condition. After the training process, participants engaged in the induction task for two minutes and completed the manipulation check measure.

Next, one of the three emotion-eliciting video clips was played in a counterbalanced order across participants. This was followed by another manipulation check measure. After completion of the measure, participants watched a distraction video clip (i.e., Alaska's Wild Denali) for 80 seconds and completed another manipulation check measure. They repeated these processes two more times until they had watched all three video clips (fear, sadness and amusement film clips). During all phases, participants' facial displays were video recorded by the webcam.

Data Analysis Methods

In this study, we tested the suggested hypotheses using multilevel modeling and follow-up simple slope analyses. First, we examined the main and interaction effects of induction and group conditions accounting for nesting of these repeated measures across different time trends. In the multilevel model, we entered main and interaction effects across induction condition, group and time as fixed effects, and intercept as random effects. The effects of induction were interpreted as meaningful only when they made a significant change across time. In addition to this, we examined the group difference in the effects of induction by testing the interaction across group, induction, and time. Therefore, in our model, "induction × time" and "group × induction × time" interactions were included as meaningful interaction terms. Other interaction terms such as "group × induction," "group × time" were not included in the full model because they were not the focus of this study, and also the inclusion of those interaction terms increase concerns for overfitting given the large number of potential interactions.

In order to test condition-specific change, we conducted simple slope analysis on the affective facial displays in each time trend (baseline to induction, or induction to video exposure). Specifically, for the hypothesis testing, main and interaction effects of induction condition, group and time were examined, and this was followed by comparison of the slopes. In addition to hypothesis testing, descriptive statistics and manipulation checks scores are provided in the results section.

Chapter 3. Results

Descriptive Statistics and Baseline Scores

Descriptive Statistics

Among 239 participants, 76 participants were in the GAD group and 74 participants were individuals with MDD. The remaining 89 participants were included as healthy controls. Mean age was 18.40 (*SD* = .63). Age did not significantly differ across the groups, $F(2, 203) = 1.008$, $p = .367$, $d = .02$. Participants were predominantly female (n = 188; 78.7%). Overall, 74.9% participants were White, 12.1% were Asian, 6.3 % were Hispanic, 3.8 % were African American, and 2.9% were other races. The screening measures were effective in forming different participant groups. The GAD group had markedly high GAD-Q-IV scores compared to the MDD group and healthy controls, $F(2, 236) = 347.49$, $p < .001$, $d = 3.41$, and the MDD group had significantly higher BDI-II scores than the GAD group and healthy controls, $F(2, 235) = 609.79$, $p < .001$, $d = 4.52$ (see Table 1).

Baseline Emotional Facial Expression Scores

There was no significant difference in baseline fear facial expression across the GAD group, MDD group, and healthy controls, $F(2, 232) = .90$, $p = .41$, $d = .00$. Sadness facial expression also did not show any significant group differences in the baseline phase, $F(2, 236) = 1.74$, $p = .177$, $d = .00$. Baseline amusement facial expression was not different across the three groups as well, $F(2, 235) = .77$, $p = .467$, $d = .00$. (see Table 2).

Manipulation Check

Manipulation Check of Worry, Rumination and Relaxation Inductions

Manipulation check results indicated that all of the induction tasks were effective in eliciting their target emotions. Worry led to significantly greater reported worry, $F(2, 707) = 333.28$, $p < .001$, $d = 1.93$, rumination made participants become significantly more ruminative,

$F(2, 707) = 436.21$, $p < .001$, $d = 2.21$, and relaxation also significantly enhanced a sense of relaxation, $F(2, 707) = 420.97$, $p < .001$, $d = 2.18$ (see Table 3).

Manipulation Check of Video Exposures

Videos used in the current study were also effective in eliciting each target emotion. The fear video clip was the most effective in inducing fear compared to the other two exposure conditions, $F(2, 707) = 234.01$, $p < .001$, $d = 1.62$. Sadness video exposure also increased sadness significantly more than the other two videos, $F(2, 707) = 807.18$, $p < .001$, $d = 3.01$. The intensity of amusement was significantly greater than the other two videos, $F(2, 707) = 480.77$, $p < .001$, $d = 2.33$.

Main Data Analysis

Data Diagnostics

Before conducting the main data analysis, we checked normality of the emotional facial expression data. The Shapiro-Wilk test indicated the emotional facial expression data was not normally distributed ($p < .05$), and therefore, we log transformed this data (i.e., log base 10). This was followed by the detection of outliers using standardized scores (Z-scores) of the log values. In the current study, Z-scores beyond ± 2.58 were determined to be extreme values and removed from the final analysis. In total, 8 values were excluded (i.e., 4 values from the induction phase, and 4 values from the video exposure phase). Using this data, we conducted multilevel modeling and slope analysis. Missing values ranged from 0 to 3% across the factorial groups, and they were due to hardware issues or calibration failure. Missing values were removed pairwise to minimize data loss.

Fear Facial Expression

There was no significant change in fear facial expression from baseline to induction time trend (see Table 5). All three slopes indicated a non-significant change from baseline to induction, worry, $\beta = -.02$, $t(156) = -.35$, $p = .730$, $d = -.06$; rumination, $\beta = .01$, $t(156) = .12$, p

= .905, *d* = .02; relaxation, β = -.04, *t*(154) = -.87, *p* = .388, *d* = -.14 (see Table 6). In addition, slopes were not significantly different across worry, rumination, and relaxation (see Table 7).

From induction to video exposure time trend, we found a marginal Induction × Time (T2) interaction, *F*(2, 227.72) = 2.44, *p* = .089, *d* = .22 (see Table 5). However, this interaction effect was not reflected well in the slope analysis. In the slope analysis, none of the slopes indicated any significant changes from induction to video exposure, worry, β = .03, *t*(156) = .65, *p* = .515, *d* = .10; rumination, β = -.05, *t*(156) = -.97, *p* = .335, *d* = -.15; relaxation, β = .06, *t*(155) = 1.20, *p* = .232, *d* = .19 (see Table 6). In addition, there was a non-significant difference between the three slopes (see Table 7). Figure 1 shows the overall trends of the fear facial expression.

Follow-up Analysis on the Fear Facial Expression

In order to examine potential causes of the non-significant results in the fear exposure condition, we analyzed the correlation between fear facial expression scores and subjectively reported fear scores. Unlike sadness and amusement facial expression scores which showed a significant correlation with their matching subjective emotions (i.e., sadness facial expression scores – subjective report scores of sadness; amusement facial expression scores – subjective report scores of amusement), sadness Person's *r*(707) = .13, *p* < .01, *d* = .26; amusement Pearson's *r*(706) = .31, *p* < .001, *d* = .65 (correlations with non-matching subjective emotions were not significant), fear facial expression scores did not show any significant correlation with subjectively reported fear scores, fear Person's *r*(702) = .003, *p* =.936, *d* = .00.

Sad Facial Expression

The Induction × Time interaction was significant from baseline to induction, *F*(2, 228.47) = 5.45, *p* = .005, *d* = .39 (see Table 5). Slope analysis showed a significant decrease in sad facial expression in both worry, β = -.08, *t*(155) = -1.66, *p* = .098, *d* = -.27 and relaxation inductions, β = -.11, *t*(157) = -2.35, *p* = .020, *d* = -.38. On the other hand, the rumination slope did not show any significant change in sad facial expression, β = .04, *t*(156) = .85, *p* = .398, *d* = .14 (see Table

6). Slope comparisons from baseline to induction time trend indicated that the increase in sad facial expression was greater in rumination than worry, *t*(311) = -1.81, *p* = .071, *d* = -.21, and relaxation, *t*(313) = 2.31, *p* = .022, *d* = .26. Worry and relaxation slopes were not significantly different from each other, *t*(312) = .42, *p* = .673, *d* = .05 (see Table 7).

In the induction to video time trend, we found a significant Induction × Time interaction, *F*(2, 222.14) = 6.64, *p* = .002, *d* = .45 (see Table 5). Unlike worry, β = .12, *t*(152) = 2.34, *p* = .021, *d* = .38, and relaxation, β = .20, *t*(152) = 4.28, *p* <.001, *d* = .69, which both showed significantly increased sad facial expressions from induction to video exposure, there was no significant increase in the rumination condition, β = .02, *t*(154) = .54, *p* = .593, *d* = .09 (see Table 6). Comparison of slopes revealed that increased sad facial expression from relaxation to the sad video was significantly greater than that from rumination to the sad video, *t*(306) = -2.78, *p* = .006, *d* = -.32. On the other hand, we found no significant difference between relaxation and worry slopes, *t*(304) = -1.16, *p* = .248, *d* = -.13, and worry and rumination slopes, *t*(306) = 1.44, *p* = .151, *d* = .16, and (see Table 7). These overall trends can be found in Figure 1.

Amusement Facial Expression

From baseline to induction, the Induction × Time interaction was marginally significant, *F*(2, 225.98) = 2.66, *p* = .072, *d* = .24 (see Table 5). Follow-up slope analysis showed that relaxation led to a significant decrease in amusement facial expression from baseline, β = -.14, *t*(152) = -3.24, *p* < .001, *d* = -.53. On the other hand, changes in amusement facial expression in worry slope, β = -.03, *t*(155) = -.51, *p* = .612, *d* = -.08, and rumination slope, β = -.026, *t*(155) = -.56, *p* = .579, *d* = -.09 were not significant (see Table 6). When slopes were compared, the relaxation slope indicated marginally greater decrease in amusement facial expression than worry slope, *t*(307) = 1.71, *p* = .088, *d* = .20, and rumination slope, *t*(308) = 1.76, *p* = .079, *d* = .20. We found no significant difference between worry and rumination slopes, *t*(311) = .01, *p* = .993, *d* = .00 (see Table 7).

Results from the induction to video exposure time trend showed a marginally significant three-way interaction between group, induction and time, $F(2, 282.32) = 1.66$, $p = .090$, $d = .30$ (see Table 5). A follow-up simple slope analysis was performed on each of the induction by group combinations at the induction to video exposure time trend. Results indicated a significant increase in all of the slopes (see Table 8). However, slope comparison analysis showed no significant differences across the slopes (see Table 9). These trends can be found in Figure 1.

Chapter 4. Discussion

The major goal of the current study was to extend CAM through an examination of emotional facial expressions. We tested whether worry or rumination allowed avoidance of a negative emotional contrast of their matching emotions (i.e., fear and sadness, respectively). In addition, we tested whether relaxation enhanced emotional contrast of negative emotions. Along with examining the effects of worry, rumination, and relaxation on negative emotional contrast, we also examined how different types of inductions affected the positive contrast process. In order to test these hypotheses, we set up a multilevel model examining the interaction between time, and induction and group in two different time trends, and compared slopes predicting fear, sad, and amusement facial expressions.

Although contrast avoidance of a fear facial expression in response to worry was hypothesized (hypotheses 1: increase of fear during worry and avoidance of fear contrast from worry to video), the current study failed to find evidence that lent support to this hypothesis. Follow-up analyses revealed a poor correlation between fear facial expression scores and subjectively perceived fear ratings, indicating that fear as measured by a composite score of the two lower face action units (i.e., Action Unit 20 & Action Unit 26) might not be a reliable indicator. Unlike sad and amusement facial expressions, which included only one or two upper face action units (i.e., sadness: inner brow raiser, and brow lowerer; amusement: cheek raiser), the fear facial expression relies more heavily on upper face action units (i.e., inner brow raiser, outer brow raiser, brow lowerer, upper lid raiser, and lid tightner). The omission of upper face action units in the current dataset was due to different experimental methods used for emotion induction tasks (i.e., participants were asked to close their eyes while they were engaging with worry, rumination, and relaxation), and this could have limited the accurate calibration of a fear facial expression. Aside from this, fear facial expressions are considered much harder to identify, compared to sad or amusement facial expressions. Studies have reported that the measurement of fear facial expressions is least accurate and most time consuming among all basic emotions in both investigator coding and computer coding systems (Mancini, Agnoli, Baldaro, Ricci Bitti, & Surcinelli, 2013; Skiendziel, Rösch, & Schultheiss, 2019; Wells, Gillespie, & Rotshtein, 2016). Furthermore, relatively poor convergent validity was reported between the conventional Facial Action Coding System and the automated emotion recognition software, which we used in the current study (Skiendziel et al., 2019). Considering these, the non-significant results in the fear process might be the consequence of the insufficient reliability and validity of the fear facial expression calibration. Therefore, we were not able to test hypothesis 1.

Unlike the fear facial expression, the pattern of sad facial expression supported hypothesis 2 well. Compared to worry and relaxation, which showed significantly less intense sadness during the induction phase, rumination induction yielded a relatively more intense sad facial expression. Furthermore, our findings showed that engagement with rumination led to a significantly less increase in sad facial expression from induction to the sad video exposure. This result is in line with our previous findings which were measured based on subjective emotional responding and electrodermal activities (Kim & Newman, 2016).

As we anticipated in hypothesis 3 (contrast enhancement of negative emotions in relaxation), relaxation enhanced negative contrast by decreasing a sadness facial expression from baseline and then increasing it from relaxation induction to sad video exposure. Due to the lack of reliability and validity of fear facial expression, we were not able to test an effect for relaxation on contrast enhancement in fear facial expression.

Although we anticipated in hypothesis 4 (contrast enhancement of amusement in worry and rumination) and 5 (less effective contrast enhancement of amusement in relaxation) that relaxation would sustain an amusement facial expression, and worry and rumination would decrease it from baseline, the results of the current study showed an opposite pattern. In the current study, relaxation decreased the intensity of amusement facial expression, and worry and rumination showed a non-significant change. This pattern is in opposition to what we have found in previous self- report data. The decrease of amusement facial expression in response to the relaxation condition might be because of the effects of applied relaxation on physiological reactivity, which is characterized by the relief of muscle tension (Öst, 1987). Considering that facial expression is created by the contraction of facial muscles, it is possible that the soothed facial musculature in response to relaxation exercise decreased the intensity of amusement facial expression. This finding indicates that the subjective perception of amusement and physiological process of amusement are highly correlated, but at the same time, their manifestations in response to relaxation exercise may be different from each other. We found a significant increase in amusement facial expression in the second time trend (i.e., induction to amusement video exposure). The increase in amusement facial expression also showed a marginally significant three-way interaction between group, induction and time. However, this interaction effect was not salient enough to yield any significant differences across the slopes.

Our study showed that emotional contrast avoidance might be a transdiagnostic phenomenon occurring across different diagnostic groups. Extending prior evidence for CAM, we also found evidence partially supporting CAM in emotional facial expressions that are less conscious/unintended emotional processes. In addition, our study showed that the assessment of emotional facial expression can be a useful way of measuring a highly complex emotion regulation phenomenon. We believe that the current findings may have many utilities in the emerging demand for computer assisted psychotherapy. For example, findings of the current study can contribute to the implementation of real-time assessment of clients' perseverative thought processes during telehealth psychotherapy. Facial expression analysis can be a useful tool in monitoring patients' progress throughout the contrast avoidance desensitization treatment. As proposed in Newman et al. (2019), the treatment of contrast avoidance can be implemented by cognitive and behavioral intervention approaches. The cognitive approach can be delivered in the form of cognitive restructuring targeting patients' fear of negative emotional contrast and their positive beliefs about worry/rumination. As a behavioral intervention, participants can decrease their aversion toward a sudden negative emotional shift by continuing engagement with a negative emotional contrast task (e.g., after fully relaxed, immediately watching visual stimuli enhancing the negative emotional experience, and repeating this process over and over again). Monitoring participants' facial expressions throughout these trials can be a useful way of measuring their progress in the contrast avoidance desensitization treatment.

However, future research is needed to delineate the following problems. As noted above, the exclusion of upper face action units limited the complete measurement of emotional facial expressions. The different protocol used for the induction condition (i.e., participants closed their eyes) could have contributed to a potential discrepancy in the intensity of facial expressions. Facial muscles are innervated by the same facial cranial nerve. Although there has been emerging evidence supporting the heterogeneity between different facial muscles, facial muscles have been conventionally considered to be interconnected to each other (Cattaneo & Pavesi, 2014). In a previous study, researchers found overlapping representations in BOLD activations for different facial movements (Krippl, Karim, & Brechmann, 2015). Without completely understanding the interdependence between upper and lower face action units, we cannot completely rule out having unexpected decrease in the overall intensity during the induction phase due to the limited contraction of upper face muscles. In order to avoid this problem, future research should use the same experiment protocol but ask participants to open their eyes throughout the entire experimental processes. Another limitation is about the characteristics of the current sample. Participants in this study were non-treatment seeking students who were highly homogeneous in terms of their age, gender, race, and education level. We expect that the inclusion of more diverse samples will improve upon the limited generalizability of the current findings.

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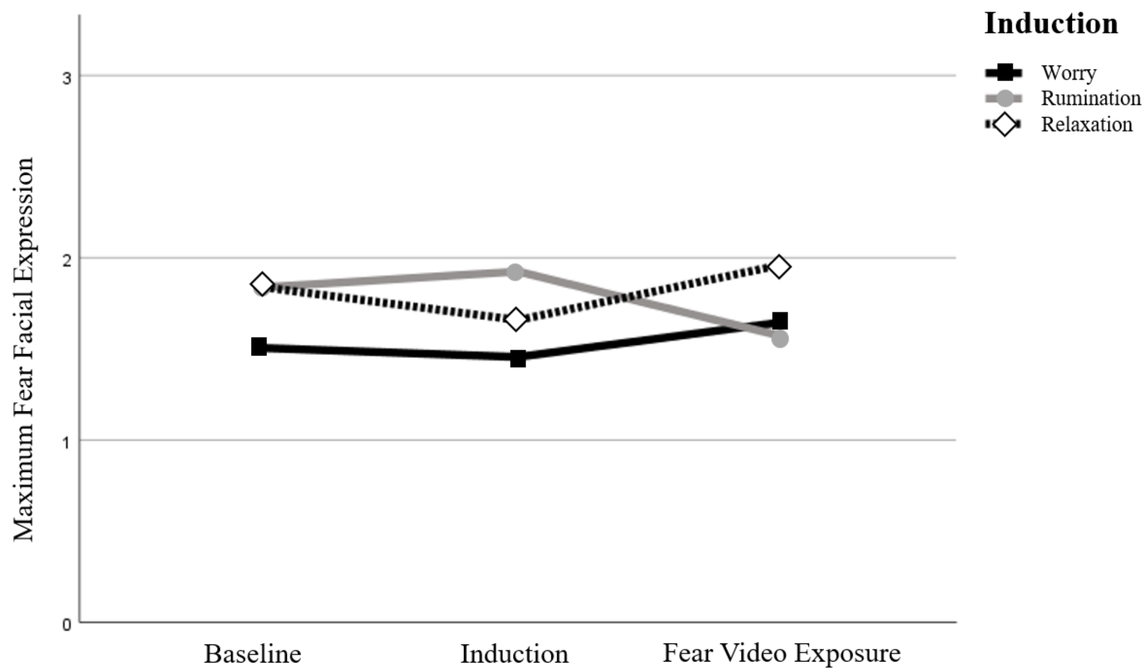
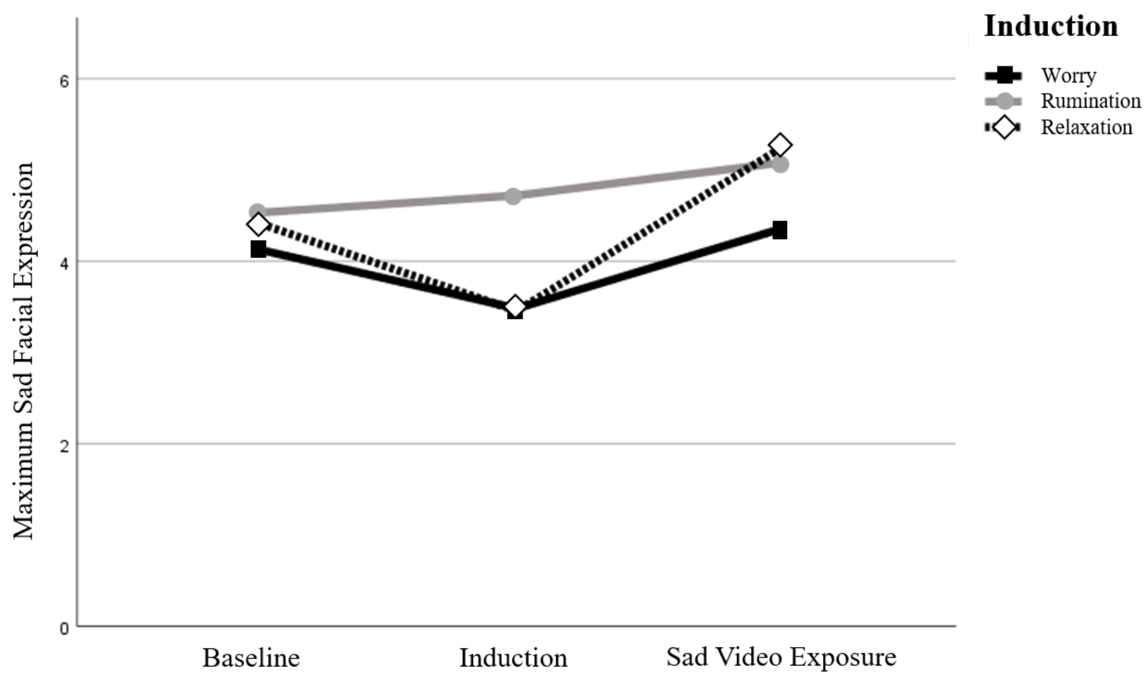
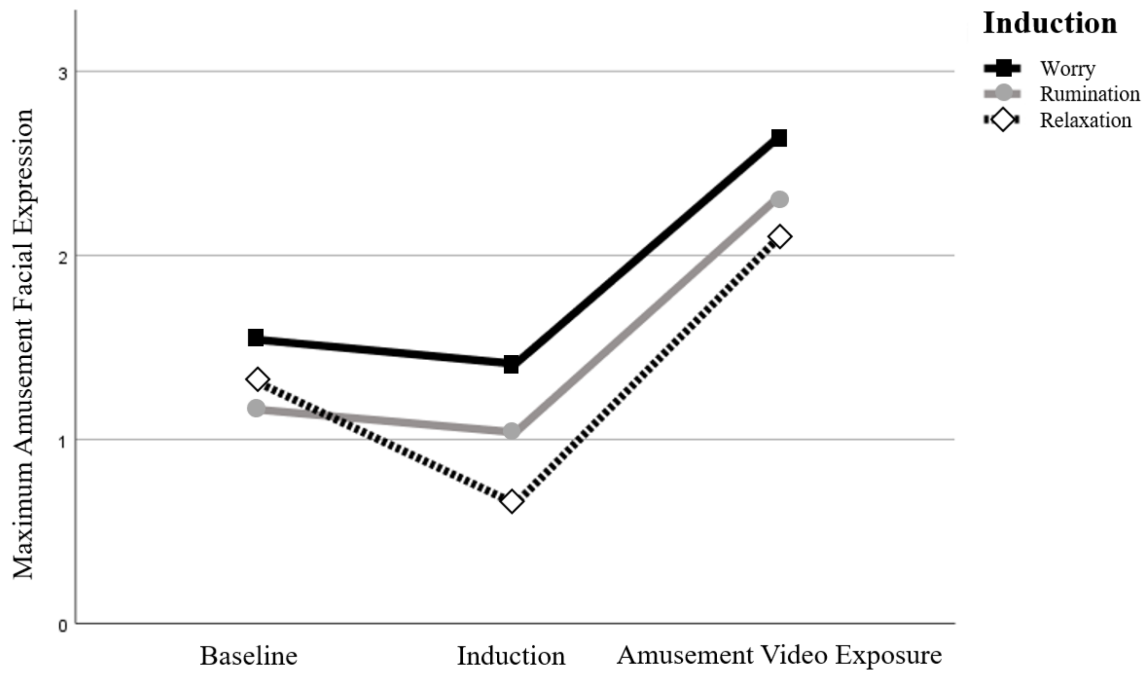
APPENDIX A: FIGURES



Fear Facial Expression from Baseline to Induction to Video Exposure



Sad Facial Expression from Baseline to Induction to Video Exposure



Amusement Facial Expression from Baseline to Induction to Video Exposure

Figure 1. Emotional Facial Expression Trends
Note. Figures are presented based on the non-transformed data.

APPENDIX B: TABLES

Table 1

Descriptive Statistics

	GAD group (*N* = 76) *M* (*SD*)	MDD group (*N* = 74) *M* (*SD*)	Control group (*N* = 89) *M* (*SD*)	*F*	*p*	*d*
Age	18.48 (.70)	18.40 (.59)	18.33 (.59)	1.01	.367	.02
GAD-Q-IV	**9.32 (1.35)**	**4.98 (2.94)**	**1.25 (1.27)**	**347.49*****	**<.001**	**3.41**
BDI-II	**8.75 (3.03)**	**24.62 (4.53)**	**4.35 (3.75)**	**609.79*****	**<.001**	**4.52**

Note. Age, Participant's age at the time of screening; GAD-Q-IV, Dimensional score of the Generalized Anxiety Disorder Questionnaire for DSM-IV; BDI-II, The Beck Depression Inventory-II, ***p < .001 (two-tailed).

Table 2

Baseline Emotional Facial Expression Scores by Participant Group

	GAD group (*N* = 76) *M* (*SD*)	MDD group (*N* = 74) *M* (*SD*)	Control group (*N* = 89) *M* (*SD*)	*F*	*p*	*d*
Fear	1.51 (1.53)	1.88 (1.76)	1.79 (1.82)	.90	.409	.00
Sadness	4.11 (2.63)	4.76 (2.51)	4.07 (2.58)	1.74	.177	.16
Amusement	1.50 (1.61)	1.16 (1.65)	1.36 (1.71)	.77	.467	.00

Note. Fear, Maximum intensity of fear facial expression (AU20 + AU26); Sadness, Maximum intensity of sad facial expression (AU15 + AU17); Amusement, Maximum intensity of amusement facial expression (AU12); Baseline facial expression scores are reported in non-transformed values.

Table 3

Manipulation Check Scores by Induction Condition

Manipulation Scale (Subjective Emotion)	Induction Type *M* (*SD*)					
	Worry (N = 237)	Rumination (N = 240)	Relaxation (N = 233)	F	p	d
Worried	4.40 (1.75)	2.78 (2.09)	.42 (.99)	**333.28*****	**<.001**	**1.93**
Ruminative	2.83 (2.30)	5.30 (1.92)	.40 (.86)	**436.21*****	**<.001**	**2.21**
Relaxed	1.96 (1.71)	2.00 (2.02)	6.43 (2.01)	**420.97*****	**<.001**	**2.18**

Note. Manipulation check scores are subjective emotional ratings; Worried, Subjective report of worry; Ruminative, Subjective report of rumination; Relaxed: Subjective report of relaxation, $^{***}p$ < .001 (two-tailed).

Table 4

Manipulation Check Scores by Video Exposure Type

Manipulation Scale (Subjective Emotion)	Exposure Type *M* (*SD*)					
	Amusement Video (N = 237)	Fear Video (N = 236)	Sadness Video (N = 237)	F	p	d
Fearful	.21 (.77)	3.78 (2.29)	1.51 (2.02)	**234.01*****	**<.001**	**1.62**
Sad	.20 (.73)	.61 (1.32)	5.07 (2.04)	**807.18*****	**<.001**	**3.01**
Amused	5.27 (2.23)	1.39 (1.84)	.46 (1.11)	**480.77*****	**<.001**	**2.33**

Note. Manipulation check scores are subjective emotional ratings; Fearful, Subjective report of fear; Sad, Subjective report of sadness; Amused, Subjective report of amusement, $^{***}p$ < .001 (two-tailed).

Table 5

Linear Mixed Model for Baseline to Induction, Induction to Exposure Time Trends, Induction, Group and Their Interactions Predicting Emotional Facial Expressions

Dependent Variable	Fixed Effect	Baseline to Induction			Induction to Exposure		
		F	*p*	*d*	*F*	*p*	*d*
Fear	Intercept	**404.35*****	**<.001**	**2.65**	**391.10*****	**<.001**	**2.60**
	Induction	1.39	.252	.12	.75	.475	.00
	Group	.86	.426	.00	.44	.646	.00
	Time	.43	.514	.00	.24	.624	.00
	Induction × Time	.41	.661	.00	**2.44**†	**.089**	**.22**
	Induction × Group × Time	.90	.531	.00	1.07	.388	.10
Sadness	Intercept	**1346.38*****	**<.001**	**4.82**	**1632.27*****	**<.001**	**5.38**
	Induction	**2.89**†	**.058**	**.25**	**3.41***	**.035**	**.29**
	Group	1.81	.166	.17	**2.35**†	**.098**	**.22**
	Time	**7.45****	**<.001**	**.33**	**32.96*****	**<.001**	**.76**
	Induction × Time	**5.45****	**.005**	**.39**	**6.64****	**.002**	**.45**
	Induction × Group × Time	1.11	.356	.12	1.51	.136	.26
Amusement	Intercept	**210.51*****	**<.001**	**1.91**	**423.58****	**<.001**	**2.69**
	Induction	**3.62***	**.028**	**.30**	**4.45***	**.013**	**.34**
	Group	1.07	.345	.05	1.56	.212	.14
	Time	**7.46****	**.007**	**.34**	**116.81*****	**<.001**	**1.41**
	Induction × Time	**2.66**†	**.072**	**.24**	.37	.690	.00
	Induction × Group × Time	1.36	.201	.11	**1.66**†	**.090**	**.30**

Note. Fear, Maximum fear facial expression (AU20 + AU26); Sadness, Maximum sad facial expression (AU15 + AU17); Amusement, Maximum amusement facial expression (AU12), Results are based on the transformed data, $^{\dagger}p < .1$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$ (two-tailed).

Table 6

Mean Emotional Facial Expression Scores at Baseline, Induction and Exposure, and Simple Slopes of Fixed Effects for Baseline to Induction and Induction to Exposure Time Trends Predicting Emotional Facial Expression Scores

Exposure Condition	Induction Type	Baseline *M (SD)*	Induction *M (SD)*	Exposure *M (SD)*	Baseline to Induction β	*t*	*p*	*d*	Induction to exposure β	*t*	*p*	*d*
Fear	Worry	1.51 (1.66)	1.46 (1.68)	1.65 (1.69)	-.02	-.35	.730	-.06	.03	.65	.515	.10
	Rumination	1.84 (1.72)	1.92 (1.86)	1.57 (1.57)	.01	.12	.905	.02	-.05	-.97	.335	-.15
	Relaxation	1.84 (1.76)	1.66 (1.82)	1.96 (1.78)	-.04	-.87	.388	-.14	.06	1.20	.232	.19
Sadness	Worry	4.09 (2.57)	3.47 (2.68)	4.35 (2.53)	**-.08**	**-1.66**†	**.098**	**-.27**	**.12**	**2.34***	**.021**	**.38**
	Rumination	4.45 (2.66)	4.70 (2.56)	5.04 (2.71)	.04	.85	.398	.14	.02	.54	.593	.09
	Relaxation	4.34 (2.54)	3.38 (2.66)	5.23 (2.38)	**-.11**	**-2.35***	**.020**	**-.38**	**.20**	**4.28*****	**<.001**	**.69**
Amusement	Worry	1.54 (1.72)	1.41 (1.69)	2.65 (1.58)	-.03	-.51	.612	-.08	**.23**	**4.86*****	**<.001**	**.78**
	Rumination	1.16 (1.61)	1.04 (1.57)	2.32 (1.74)	-.03	-.56	.579	-.09	**.23**	**4.87*****	**<.001**	**.78**
	Relaxation	1.33 (1.66)	.52 (1.21)	2.10 (1.81)	**-.14**	**-3.24****	**.001**	**-.53**	**.27**	**5.85*****	**<.001**	**.93**

Note. Fear, Maximum fear facial expression (AU20 + AU26); Sadness, Maximum sad facial expression (AU15 + AU17); Amusement, Maximum amusement facial expression (AU12), Means and standard deviations are reported in non-transformed values, Slopes are based on the transformed data, $^{\dagger}p < .1$, $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$ (two-tailed).

Table 7

Simple Slope Comparison by Induction Type (Emotional Facial Expression scores)

Dependent Variable	Slope	Worry vs. Rumination *t*	*df*	*p*	*d*	Worry vs. Relaxation *t*	*df*	*p*	*d*	Rumination vs. Relaxation *t*	*df*	*p*	*d*
Fear	T1 (B to I)	-.33	312	.744	-.04	.38	310	.706	.04	.69	310	.488	.08
	T2 (I to V)	1.14	312	.253	.13	-.38	311	.702	-.04	-1.53	311	.126	-.17
Sadness	T1 (B to I)	**-1.81**†	**311**	**.071**	**-.21**	.42	312	.673	.05	**2.31***	**313**	**.022**	**.26**
	T2 (I to V)	1.44	306	.151	.16	-1.16	304	.248	-.13	**-2.78****	**306**	**.006**	**-.32**
Amusement	T1 (B to I)	.01	311	.993	.00	**1.71**†	**307**	**.088**	**.20**	**1.76**†	**308**	**.079**	**.20**
	T2 (I to V)	-.09	310	.928	-.01	-.60	313	.551	-.07	-.50	313	.620	-.06

Note. Fear, Maximum fear facial expression (AU20 + AU26); Sadness, Maximum sad facial expression (AU15 + AU17); Amusement, Maximum amusement facial expression (AU12); T1 (B to I), Slope from baseline to induction; T2 (I to V), Slope from induction to video exposure, Results are based on the transformed data, $^{\dagger}p < .1$, $^{*}p < .05$, $^{**}p < .01$ (two-tailed).

Table 8

Means of Dependent Variables at Induction and Exposure, and Simple Slopes of Fixed Effects by Induction and Group for Induction to Exposure Time Trends Predicting Amusement Facial Expression Scores

Induction Type	Group (*N*)	Induction *M* (*SD*)	Exposure *M* (*SD*)	Induction to Exposure (T2)			
				β	*t*	*p*	*d*
Worry	GAD (54)	.25(.31)	.57(.23)	.31	4.22	.000	1.17
	MDD (46)	.16(.29)	.38(.30)	.22	2.54	.015	.76
	Controls (57)	.38(.31)	.52(.25)	.15	1.95	.057	.53
Rumination	GAD (59)	.17(.28)	.43(.31)	.26	3.43	.001	.91
	MDD (45)	.19(.28)	.35(.32)	.15	1.72	.092	.53
	Controls (53)	.24(.32)	.50(.28)	.26	3.12	.003	.87
Relaxation	GAD (38)	.16(.29)	.41(.33)	.25	2.47	.019	.82
	MDD (56)	.14(.26)	.46(.31)	.31	4.13	.000	1.12
	Controls (66)	.09(.21)	.32(.32)	.23	3.47	.001	.87

Note. Predictor: group by time (induction to exposure) interaction; Dependent variable: amusement facial expression

Table 9

Simple Slope Comparison by Induction Type and Group (Amusement Facial Expression scores)

Dependent Variable	Time Trend	Induction Type	GAD vs. MDD				GAD vs. Controls				MDD vs. Controls			
			t	*df*	*p*	*d*	*t*	*df*	*p*	*d*	*t*	*df*	*p*	*d*
Amused	Induction to Exposure	Worry	.81	96	.423	.16	1.57	107	.120	.30	.64	99	.527	.13
		Rumination	.93	100	.352	.19	.04	108	.965	.01	-.86	94	.390	-.18
		Relaxation	-.50	90	.619	-.11	.15	100	.882	.03	.80	118	.426	.15

Note. Predictor: group by time (induction to exposure) interaction; Dependent variable: amusement facial expression

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Kim H., Lu, X., Costa, M., Kandemir, B., Adams, R. B., Li, J., Wang, J. Z., & Newman, M.G. (2018). Development and validation of Image Stimuli for Emotion Elicitation (ISEE), *Psychiatry Research, 261*, 414-420. doi: 10.1016/j.psychres.2017.12.068

Newman, M. G., Cho S., & **Kim H.** (2017) Worry and generalized anxiety disorder: A review. *Neuroscience and Biobehavioral Psychology*. doi:10.1016/B978-0-12-809324-5.05108-7

Youn, S., Xiao, H., **Kim H.**, Castonguay, L., McAleavey, A., Newman, M.G., Safran, J. (2016) *Effective and less effective therapists for generalized anxiety disorder: Are they conducting therapy the same way?*

Lee, Y., **Kim, H.**, Nam, S., Jin, L., Yang E. (2011). The acculturation experience of Chinese international students in South Korea: Coping and perceived changes in the cultural transition. *The Korean Journal of School Psychology*, 8(3).

Lee, J., Kang, S., **Kim, H.**, Lee, Y., & Yang, E. (2010). Risk and protective factors perceived by school dropouts, *The Korea Journal of Youth Counseling*, 18(2), 225-241.

Chun, Y., Woo, S., **Kim, H.**, Kang, C., & Yang, E. (2009). The relationships between children`s interpersonal types and parental factors. *The Korean Journal of School Psychology*, 6(2), 103-122.

Honors and Awards	**Grantor**	**Year**
IST Seed Grant	Penn State University	2016
Bruce V. Moore Graduate Fellowship	Penn State University	2014
NSF Research Fellowship	National Science Foundation	2013
University Graduate Fellowship	Penn State University	2012
Brain Korea 21 Research Fellowship	Korean Ministry of Education	2008