Expressive Regulation and Health

Does the ability to regulate the expression of emotion predict physical health outcomes?

Natalie Louise Tuck

A thesis submitted in fulfilment of the requirements of
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Abstract

The relationship between emotion regulation and physical health has been of considerable scientific and public interest since at least the time of Freud. In general, openly expressing emotions is framed as a hallmark of adaptive behaviour, whereas suppressing emotions and 'bottling them up' is widely thought to have a detrimental impact on mental and physical health. However, closer examination of the evidence base supporting these claims reveals an over reliance on self-reported measures and a near exclusive focus on trait regulation.

Traits represent only one part of the broader emotion regulatory construct, and re-directing attention towards the assessment of expressive skills or abilities is more consistent with both evolutionary and functionalist accounts of emotion. Furthermore, recent advances in emotions theory suggest that the *ability* to regulate the expression of emotion in a manner that fits with personal goals and motivations should be associated with better outcomes. In support of this possibility, accruing empirical work indicates that greater regulatory skill predicts better psychological wellbeing. However, whether ability-based assessments of expressive regulatory skill are also associated with physical health has not yet been systematically examined.

In addressing this gap in the literature, three studies tested whether expressive regulatory skills were associated with physical health indices. A first study based on 117 men and women found that the ability to both enhance and suppress expressivity predicted better self-reported health and had mixed links with heart rate variability (HRV). A second study (N=80 women) demonstrated that skill in rapidly expressing discrete emotions also predicted outcomes, with findings detailed across two reports. The first showed that higher HRV predicted greater skill in expressing some emotions, and the second showed that greater skill predicted better self-reported outcomes and

had mixed links with immune parameters. Finally, a third study (N=82 men and women) found that greater skill in expressing positive emotion predicted lower cardiovascular disease (CVD) risk among men.

In moving beyond the limitations of trait assessments, findings from across this programme of doctoral research offer initial evidence that greater expressive regulatory skill predicts better subjective and objective health outcomes. These findings suggest that rather than any single regulatory strategy (such as suppression) predicting better or worse outcomes, the ability to flexibly regulate the expression of emotion in accordance with situational demands represents a useful way of thinking about adaptive emotion regulation.

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Natalie Tuck, November 2016

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Tuck, N. L., Adams, K. S., Pressman, S. D., & Consedine, N. (2017). Greater ability to express positive emotion is associated with lower projected cardiovascular disease risk. Journal of Behavioral Medicine. doi:10.1007/s10865-017-9852-0

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Sarah Pressman	Processing and analysis of photographic data and reviewing the final manuscript
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Chapter 1 : Overview

1:1 Background

The study of emotion has a rich history dating from Darwin (1872/1965) to early theorists including Aristotle (1913) (see J. A. Russell, 1994), however, the idea that suppressing the outward expression of emotion has adverse consequences was made prominent by Freud's proposal that wellbeing depends upon the regulation of emotional 'impulses' (Breuer & Freud, 1957/1895; Freud, 1923/1961). In this view, suppressed emotions manifest in physical and psychological symptoms, and the release of suppressed emotion was widely considered to be a core therapeutic target (Breuer & Freud, 1957/1895; Freud, 1915/1957, 1923/1961, 1930/2015). The formalisation of psychosomatic medicine increased interest in the potential links between the suppression of emotion and physical health (e.g. Alexander, 1939), with expressive suppression thought to play a role in the development and maintenance of pain (Engel, 1959) gastrointestinal problems (Alexander, 1950), cardiovascular disorders (Alexander, 1939, 1948) and, more recently, cancer (Fawzy et al., 1993; Gross, 1989), and infectious diseases (Pennebaker, Kiecolt-Glaser, & Glaser, 1988).

Although some of this early work has since been discredited, the notion that inhibiting the expression of emotion has a negative impact on health persists in public perception, clinical practice, and research, and remains a fundamental tenet of contemporary psychosomatic medicine (e.g. DeSteno, Gross, & Kubzansky, 2013; Haga, Kraft, & Corby, 2009; Mauss & Gross, 2004). However, as will become apparent in the following chapters, convincing evidence linking expressive suppression with poorer outcomes is surprisingly meagre, and both conceptual and methodological limitations call into question the notion that expressive suppression is universally deleterious.

1.2 Research questions

Although the majority of work documenting links between suppression and outcomes is based on the assessment of traits, the present thesis addresses the possibility that an alternative approach to the conceptualisation and measurement of expressive regulation is needed. Specifically, it is suggested that an ability-based approach ameliorates many of the limitations inherent in self-reported trait assessments, and may thus offer a more suitable conceptualisation of expressive regulation as it pertains to physical health. As will become clear, although both theoretical and empirical work supports this possibility (e.g. Bonanno, Papa, Lalande, Westphal, & Coifman, 2004; Levy-Gigi et al., 2016; Rozanski & Kubzansky, 2005; Westphal, Seivert, & Bonanno, 2010), studies have not yet directly tested whether objective tests of the *ability* to regulate the expression of emotion is associated with *physical* health outcomes.

At its core then, this thesis addresses the overarching question of whether the *ability* to regulate the expression of emotion is associated with better physical health outcomes. Within this general framework, specific questions regarding the types of health outcomes that are associated with expressive regulatory skills, and the operationalisations of expressive skill that are most predictive of outcomes are also considered.

1.3 Overview of methodology

These general research questions are investigated across three empirical studies which complement, and build on one another in terms of both the operationalisation of expressive skill as well as the health indices that are assessed.

Study 1 (N = 117) uses an established expressive skill paradigm (e.g. Bonanno et al., 2004), to test whether the ability to flexibly up- and down-regulate facial expressions of joy, sadness, and anger (in response to standardised emotion-eliciting stimuli) is associated with self-reported symptom interference, and high frequency heart rate variability (HRV).

Study 2 (N = 80) then evaluates a novel and more portable operationalisation of expressive skill (the ability to deliberately signal a range of emotions in the absence of underlying affect), and presents two empirical reports. The first is a replication and extension of Study 1, testing whether HRV is associated with the ability to signal specific discrete emotions (final N=72 due to some missing HRV data). The second report tests whether the ability to signal discrete emotions is associated with immunoregulatory molecules; interleukin-6 (IL-6), interleukin-8 (IL-8), interleukin-4 (IL-4), tumour necrosis factor (TNF), interferon-gamma (IFN-y), and C-reactive protein (CRP). This report also investigates the links between expressive skill and self-reported depressive symptoms, anxiety, perceived health, and symptom counts, and tests whether objective, performance-based tests of emotional knowledge also predict health outcomes (N=80).

Finally, Study 3 (N=82) extends the thesis towards the measurement of clinically relevant health outcomes by testing whether the ability to signal positive emotion (specifically) is associated with three objective indices of projected 5- and 10-year cardiovascular disease (CVD) risk. This study also tests for possible gender moderation.

All three studies were based on physically healthy, non-patient populations. Studies 1 and 3 employed community samples of men and women from across the lifespan, whereas Study 2 was based on a more restricted, homogenous sample of women aged 18 - 35. As noted, Studies 1 and 3 were each used to produce a single empirical report, whereas two reports were derived from Study 2. As such, there is some data overlap in the two Study 2 manuscripts; a fact that was acknowledged throughout the submission and peer review process.

Additionally it is worth noting that heart rate variability can be measured in both time and frequency domains, and can be further differentiated into low- and high-frequency measures. Each of the studies in this thesis assessed high frequency heart rate variability. However, the generic term HRV is used throughout the thesis to obviate the need to distinguish between the specific types of HRV measurements used in prior studies. The one exception to this pattern is that, to retain consistency with the published article, Chapter 7 uses the term vagally-mediated HRV (vmHRV).

Finally, because it is problematic to adapt published and copyrighted articles, each manuscript is presented as the final Microsoft Word version of the published paper. In keeping the integrity of the published/submitted manuscripts, three feature American spelling, whereas one uses British spelling. There is also some minor repetition across papers, notably in the Methods sections.

1.4 Thesis structure

As described above, three research questions were addressed across four empirical reports, testing the links between diverse operationalisations of expressive regulatory skill/knowledge, and a range of physical health indices.

Chapter 1 (above) provides a brief historical background, delineating the origins of the dominant trait-based approach to the assessment of emotion regulation. Following this, it is suggested that a skills-based approach may offer a more useful means of thinking about emotion regulation in the context of health. The principle research questions are then outlined before an overview of the thesis methodology is presented.

Chapter 2 summarises the two core bodies of literature that generally support the view that expressive suppression predicts worse outcomes. This chapter shows that both experimental studies (in which suppression is manipulated in the laboratory), and epidemiological/cross-sectional work based on self-reported trait expressivity, consistently report that expressive suppression predicts poorer physical and psychological outcomes.

Chapter 3 then critiques this work by suggesting that limitations in the designs and operationalisations employed in both experimental and epidemiological studies undermine confidence in the idea that expressive suppression is uniformly deleterious.

Chapter 4 complements this critique by providing a rationale for adopting a skills-based approach to the assessment of expressive regulation. It is suggested that the assessment of regulatory skills has both methodological and conceptual advantages over trait assessments and may thus offer a more suitable means of operationalising expressive regulation as it pertains to health.

Chapter 5 then summarises the thesis rationale before formally presenting the research questions; (1) do objective assessments of expressive regulatory skill predict physical health outcomes, (2) what types of health outcomes are associated with skill-based operationalisations, and (3) which operationalisations of expressive regulatory skill are predictive of physical health?

Chapter 6 suggests that the ability to flexibly regulate the expression of felt emotion may show links to physical health outcomes. Following this, the first empirical report is presented, which tests whether the ability to up- and down-regulate expressions of sadness, anger, and joy in response to emotion-eliciting videos predicts self-reported symptom interference and HRV.

Chapter 7 then broadens the focus beyond these three emotions, and addresses the possibility that skill in rapidly signalling discrete emotions in the absence of underlying affect may also predict outcomes. This chapter then presents the second empirical study, which investigates the relationships between the ability to signal six discrete emotions and HRV.

Chapter 8 then considers the possibility that in addition to HRV, the ability to signal discrete emotions (in the absence of emotional stimuli) may predict self-reported health and wellbeing, as well as further objective health-relevant measures. This chapter then presents the third empirical report, which tests whether the ability to signal specific emotions is associated with self-reported physical and psychological health, together with a range of immunoregulatory molecules. This chapter also investigates links between a performance-based assessment of emotional knowledge and both self-reported outcomes and immunoregulatory molecules.

Chapter 9 begins by noting that although both immune parameters and HRV are important indices of physiological functioning that are frequently interpreted as health proxies, neither can be classified as health *outcomes*. In addressing this limitation, the final empirical study evaluates whether the ability to signal positive emotion is associated with clinically relevant measures of projected CVD risk.

Chapter 10 then integrates results across the four reports and provides a general discussion, focusing on the three primary research questions, before outlining possible mechanisms and clinical applications. Limitations and possible areas for future research are then considered before the thesis' overall contribution is summarised in Chapter 11.

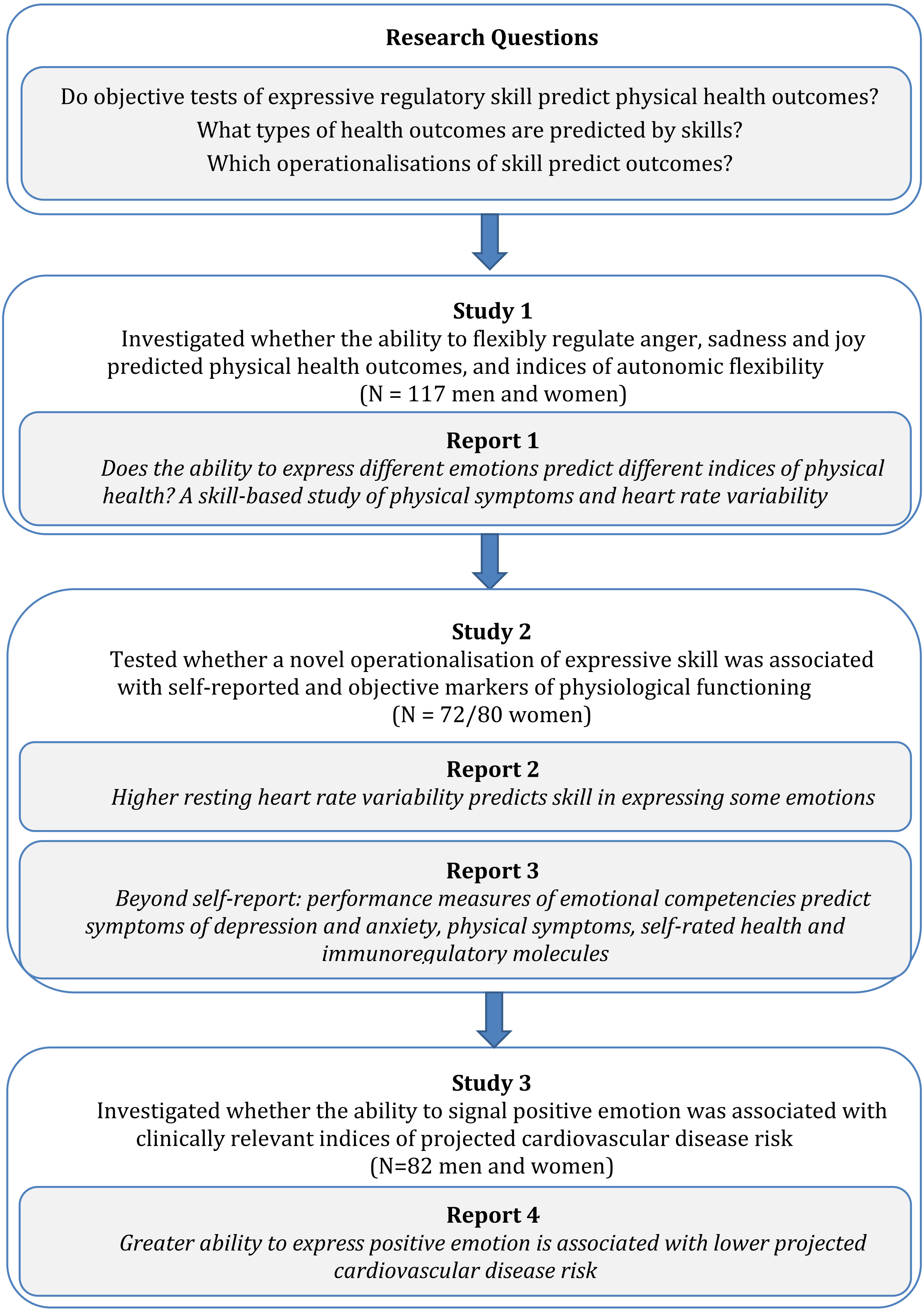

Figure 1.1: Overview of the programme of doctoral study

Chapter 2 : Expressive regulation; current conceptualisations and links to health

2.1 Overview

This chapter begins by describing current conceptualisations of emotion and emotion regulation, before summarising evidence from the two dominant methodological approaches that have investigated the links between expressive regulation and outcomes. First, findings from experimental work documenting the short-term physiological, cognitive, and social consequences of expressive regulation are summarised. Following this, key findings from cross-sectional and prospective studies are presented which suggest that the self-reported tendency to suppress emotion is typically associated with worse physical and psychological wellbeing.

2.2 Current conceptualisations of emotion and emotion regulation

One of the primary challenges facing emotion regulation research is a lack of conceptual clarity regarding what emotion - and consequently what emotion regulation - actually entail (e.g. Burns, Quartana, & Bruehl, 2008; Consedine & Mauss, 2014; Gross & Thompson, 2007; A. R. Lewis, Zinbarg, & Durbin, 2010; Thompson, 1994). Given that the meaningful study of emotion regulation (and its links to health) is predicated on a consensual definition of emotion (Gross, 1998b, 2015), this chapter begins by describing the ways in which emotion, and emotion regulation are characterised throughout this thesis.

Although a concise definition is elusive, there is a general agreement that emotions are best described as short-lived, biologically-based reactions, which are comprised of loosely coupled experiential, expressive, and physiological response tendencies (Gross, 1998b; Lang, Rice, & Sternbach, 1972; Mauss, Levenson, McCarter, Wilhelm, & Gross, 2005). These response tendencies function to coordinate the ways in which we address challenges and opportunities in our environment, and are modulated in order to increase the likelihood of survival and/or reproductive success (Ekman, Rolls, Perrett, & Ellis, 1992; Frijda, 1986; Lang et al., 1972; Levenson, 1999; C. A. Smith & Lazarus, 1990; Tooby & Cosmides, 1990).

Among the most important facets of our environment are our social relationships; successful social functioning is pivotal to physical and psychological wellbeing (Baumeister & Leary, 1995; Cacioppo & Cacioppo, 2014; Holt-Lunstad, Smith, Baker, Harris, & Stephenson, 2015; Momtaz et al., 2012). Humans are motivated by a need for co-operation and affiliation, but are also driven to compete with others, enhance our own social standing, and avoid social threats (Fischer & Manstead, 2008). In addressing these social motivations, it is increasingly accepted that emotions, and the expression of emotions, play a role in regulating our social interactions in accordance with both affiliative and competitive goals (Fischer & Manstead, 2008; Frijda & Mesquita, 1994; Keltner & Haidt, 1999; Morris & Keltner, 2000; Owren & Bachorowski, 2001).

Consistent with this view, functionalist accounts propose that facial expressions of emotion may be best conceptualised as social signals that facilitate the rapid sharing of information between conspecifics (Fridlund, 1997; Hareli & Hess, 2010; Owren & Bachorowski, 2001; Schmidt & Cohn, 2001; Tooby & Cosmides, 1990). Rather than being direct readouts of internal emotional states, it has been proposed that facial expressions may be better described as signals of behavioural intent (see Fernández-Dols & Ruiz-Belda, 1995; Fridlund, 1991a; Hecht & LaFrance, 1998; Kraut & Johnston, 1979; W. J. Smith, 1977), that can be deliberately or automatically adjusted in ways that influence both social processes (Coté, 2014; Hareli & Hess, 2012) and internal physiological and psychological states (Giuliani, McRae, & Gross, 2008; Gross, 1998a;

Kraft & Pressman, 2012). As such, despite continued debate regarding whether expressions are necessarily related to underlying feeling states *at all* (see Bonanno & Keltner, 2004; Fridlund, 1991a), there is a general consensus that expressions can be exaggerated, faked, maintained, and concealed in order to regulate the type and amount of information that is shared with others (e.g. Ekman, 1994; Ekman & Friesen, 1969; Hareli & Hess, 2012; Izard, 1994; Mitchell, 1999).

For example, although smiles are synonymous with being happy, individuals also smile to be polite (Bonanno et al., 2002), as a signal of power (Hecht & LaFrance, 1998), when concealing negative emotions and/or being deceptive (Ekman, 2009; Ekman & Friesen, 1982; Ekman, Friesen, & O'Sullivan, 1988), and when seeking to appease (Prkachin & Silverman, 2002). Indeed smiles occur in most human encounters (Lockard, Fahrenbruch, Smith, & Morgan, 1977), regardless of underlying affect (Fridlund, 1991b; Hecht & LaFrance, 1998; Hess, Banse, & Kappas, 1995). For instance, individuals smile when discussing bereavement (Bonanno & Keltner, 1997), and when they are embarrassed (Keltner, 1995; Keltner & Buswell, 1997), distressed, afraid, and angry (Ekman & Friesen, 1982). As such, although there are times when expressions *may* reflect underlying emotion, facial expressions are also deliberately and/or automatically regulated in a manner that may be more reflective of social factors than underlying feeling states.

Emotion regulation then, refers to the process of modifying the trajectory of these experiential and/or expressive response tendencies (Gross, 1998b; Koole, 2009; Mauss, Evers, Wilhelm, & Gross, 2006; Peña-Sarrionandia, Mikolajczak, & Gross, 2015). Given that emotions are dynamic and unfold over time, the process model of emotion regulation provides a useful framework for organising regulatory strategies based on the juncture in the emotion generative process at which they exert an impact (Gross, 1998b). In brief, Gross' process model categorises regulatory strategies as antecedent- (occurring before response tendencies are activated) or response-focused (occurring once emotions are active). Antecedent-focused strategies include efforts to regulate the environment (situation selection and modification), adjust the focus of attention (attentional deployment), and alter the way in which emotional stimuli are interpreted (cognitive reappraisal) (Gross, 1998a, 1998b; Gross & Levenson, 1993). Conversely, response-focused strategies are characterised by efforts to modulate the experiential and/or expressive components of an emotion once it is already active. Within this model then, expressive regulation is a response-focused strategy, thought to occur late in the emotion-generative process, termed response modulation (Gross, 1998b). However, for consistency and ease of understanding, the terms expressive regulation and/or expressive suppression will be used throughout this thesis.

Of greatest relevance to the current body of work, the *degree* to which emotions are regulated has been repeatedly implicated in physical and psychological wellbeing. Although the functionalist account outlined earlier in this chapter suggests that the ability to both enhance and suppress expressions should predict better outcomes, it is more widely accepted that openly expressing emotions is a hallmark of adaptive behaviour, whereas suppressing emotions and 'bottling them up' is thought to have a detrimental impact on wellbeing (John & Gross, 2004; Mauss & Gross, 2004; Pennebaker & Beall, 1986).

Indeed, expressive regulation (particularly suppression) is among the most widely studied emotion regulatory strategies (e.g. Emery & Hess, 2011; Haga et al., 2009; Koval, Butler, Hollenstein, Lanteigne, & Kuppens, 2015; Vieillard, Harm, & Bigand, 2015), and work testing links between expressive suppression and outcomes can be broadly characterised as falling into one of two dominant methodologies. The first is based on between-group, experimental designs which test the degree to which manipulated expressive suppression exerts an immediate impact on physiological, affective, cognitive, and social processes. The second is comprised of cross-sectional and prospective studies which assess the extent to which individual differences in self-reported trait suppression are associated with a range of health outcomes. Below, the core findings from these two research traditions are summarised.

2.3 Experimental Work: Manipulated expressive regulation and outcomes

The degree to which manipulated expressive regulation exerts an immediate impact on physiological, affective, cognitive, and social processes has been widely investigated using between-subjects, experimental paradigms (e.g. Giuliani et al., 2008; Goldin, McRae, Ramel, & Gross, 2008; Gross, 1998a; Gross & Levenson, 1993; Gross & Levenson, 1997). Traditionally, this approach has randomised participants to either suppress their facial expressions or to engage in an alternative regulatory strategy or control condition, while viewing emotionally evocative stimuli. By experimentally manipulating the use of expressive suppression, this approach has allowed investigators to identify the immediate impact that expressive suppression has on a range of outcomes.

Broadly, the most consistent finding stemming from this literature is that expressive suppression incurs cognitive, social, and physiological costs, but has little impact on underlying feeling states (Bonanno et al., 2004; Gross & John, 2003; Korb, Grandjean, Samson, Delplanque, & Scherer, 2012; Kunzmann, Kupperbusch, & Levenson, 2005). These findings are generally interpreted as evidence that expressive suppression is "less effective" in regulating emotion, while being simultaneously more physiologically, cognitively and socially demanding than other strategies. Findings are summarised below.

Cognitive costs of expressive suppression

Experimental work has repeatedly found that compared with other regulatory strategies, expressive suppression leads to deficits in subsequent cognitive performance (Schmeichel, Vohs, & Baumeister, 2003), particularly memory (Bonanno et al., 2004; Egloff, Schmukle, Burns, & Schwerdtfeger, 2006; Emery & Hess, 2011; Pu, Schmeichel, & Demaree, 2010; Richards & Gross, 2000). For example, in a series of studies in which expressive suppression was manipulated while participants viewed emotionally evocative stimuli, it was found that compared with cognitive reappraisal, those randomised to a suppress condition had poorer memory for details of the emotional stimuli (Richards & Gross, 2000). Interpretatively, it is thought that these cognitive impairments are caused by attention being directed away from processing emotional stimuli, and towards the regulation of facial musculature (Richards & Gross, 2000).

It follows that if expressive suppression requires directing attention towards effortful regulation, then suppression may also reduce the capacity to engage in other self-regulatory behaviours via ego depletion. Ego depletion refers to the process by which effortful regulation over one aspect of behaviour, reduces the capacity to exert control over other, subsequent behaviours (Baumeister & Vohs, 2007). If expressive suppression contributes to ego depletion, then this may partially explain the links between trait suppression and physical health (e.g. Baumeister, Gailliot, DeWall, & Oaten, 2006; Hagger, Wood, Stiff, & Chatzisarantis, 2010; Muraven & Baumeister, 2000). For example, experimentally manipulated expressive suppression has been shown to reduce the capacity to engage in deliberate goal-directed behaviour (Hofmann, Rauch, & Gawronski, 2007) including healthy eating (Vohs & Heatherton, 2000). However, recent difficulties replicating the ego depletion effect go some way towards undermining this interpretation (Hagger et al., 2015).

Social costs of expressive suppression

Furthermore, given that social interactions require substantial cognitive attention, whereas expressive suppression appears to direct attention inwards, away from external stimuli, suppression may have a detrimental impact on interpersonal functioning (Butler et al., 2003). Consistent with this view, studies have found that manipulated expressive suppression reduces the capacity to communicate effectively, build rapport, form relationships (Butler et al., 2003), and recognise facial expressions in others (Schneider, Hempel, & Lynch, 2013). Expressive suppression also reduces interpersonal responsiveness, while increasing negative partner-perceptions, and hostile behaviour (Butler, Lee, & Gross, 2007). Given established links between social functioning and health (Cacioppo & Cacioppo, 2014; Petitte et al., 2015), with both hostility (K. A. Matthews, Gump, Harris, Haney, & Barefoot, 2004), and social isolation (Holt-Lunstad et al., 2015) predicting greater cardiovascular risk, expressive suppression may adversely influence heath due to a deleterious impact on social relationships.

Physiological costs of expressive suppression

In addition to cognitive and social costs, experimental studies have consistently found that expressive regulation in general, and expressive suppression in particular, produces changes in physiological activation. Manipulated suppression appears to reduce heart rate and somatic activity (Gross, 1998b; Gross & Levenson, 1993; Gross & Levenson, 1997), while increasing both systolic and diastolic blood pressure (Burns, Quartana, & Bruehl, 2007; Butler et al., 2003), and general activation of the cardiovascular system (Demaree, Schmeichel, Robinson, & Everhart, 2004; Demaree, Schmeichel, et al., 2006; Gross, 1998a; Gross & Levenson, 1993; Gross & Levenson, 1997; Lanzetta, Cartwright-Smith, & Eleck, 1976; Vaughan & Lanzetta, 1981; Zuckerman, Klorman, Larrance, & Spiegel, 1981). As such, it has been proposed that the repeated use of expressive suppression, and resulting physiological activation, may have a cumulative detrimental impact on cardiovascular health (Everson-Rose & Lewis, 2005; Krantz & Manuck, 1984; Manuck & Krantz, 1986; Rozanski, Blumenthal, & Kaplan, 1999). However, this possibility has not yet been explicitly tested, a point that is revisited in Chapter 4.

Pain related costs of expressive suppression

Finally and perhaps related to evidence of physiological reactivity, studies have found that expressive suppression increases sensitivity to painful stimuli in both student samples (Quartana & Burns, 2007; Quartana, Yoon, & Burns, 2007) and chronic pain patients (Burns, Quartana, Gilliam, et al., 2008; Burns et al., 2012). For example, in a study of lower-back-pain patients, those randomised to a suppress condition while being exposed to harassment, responded with greater muscle tension and blood pressure than those who were not instructed to suppress expressions. Further, when completing a subsequent task mimicking daily activities, those who had suppressed expressions demonstrated more pain behaviours, with changes in blood pressure and muscle tension partly mediating the links between suppression and subsequent pain behaviour (Burns et al., 2012). These findings suggest that expressive suppression, and the resulting physiological reactivity, and/or attentional factors (see Burns, Quartana, Gilliam, et al., 2008; Quartana & Burns, 2007), may increase the perception of pain and/or other physical symptoms. As such, habitual use of expressive suppression may increase perceived pain, physical symptoms, and functional disability, with potential long term implications for functional capacity and physical health (see Mayne, 1999; Watson & Pennebaker, 1989).

Overall, this body of experimental work indicates that expressive suppression influences physiological, cognitive, and social processes, along with somatic perception. However, despite offering comprehensive evidence that expressive suppression increases activation of the cardiovascular system, work in this tradition has not directly tested whether expressive suppression leads to worse health *outcomes*. As is discussed more fully in Chapter 4, indices of physical activation do not necessarily result in long-term health consequences. However, in an effort to address this limitation, data based on trait assessments do indicate that habitual suppression predicts poorer physical health over time (Gross & John, 2003; John & Gross, 2004), and findings from this second body of work are outlined below.

2.4 Epidemiological work: Self-reported suppression and outcomes

The investigation of whether trait measures of expressive suppression are associated with physical health has its roots in epidemiological and clinical literature, and stems from early observations that particular patient groups could be characterised by stereotypical patterns of low or inhibited emotional expressivity (Alexander, 1939, 1950; Halliday, 1937).

Trait suppression can be defined as the general tendency to inhibit the visible expression of emotion, particularly in the face, whereas trait expressivity refers to the tendency to outwardly signal felt emotions. Although there are numerous measures of trait expressive regulation, among the most frequently used in recent times is the Emotion Regulation Questionnaire (ERQ) (Gross & John, 2003). This is a 10-item scale designed to measure the degree to which a person typically regulates emotion by using expressive suppression and cognitive reappraisal on a Likert scale ranging from 1 (strongly disagree) to 7 (strongly disagree). On this scale, trait expressive suppression is indexed by items such as "when I am feeling positive emotions, I am careful not to express them" and "I control my emotions by not expressing them."

Over the past 30 years, the development of self-reported measures of trait regulation, such as the ERQ has seen exponential growth in work testing whether regulatory tendencies are associated with physical health outcomes, most notably CVD (e.g. Appleton & Kubzansky, 2014; Grande, Romppel, & Barth, 2012; Haynes, Feinleib, & Kannel, 1980; Kubzansky, Park, Peterson, Vokonas, & Sparrow, 2011; Mols & Denollet, 2010a; Sapolsky, 2007). Below, studies documenting links between self-reported trait regulation and three types of health metrics; health behaviours, pain sensitivity and cardiovascular risk, are summarised.

Trait suppression and health behaviours

In exploring the pathways linking expressive suppression with health outcomes, one possibility is that people reporting high trait suppression, will show less engagement in healthy behaviours. Studies investigating this possibility indicate that trait suppression is associated with lower physical activity, increased likelihood of smoking, poorer diet, higher body mass index (BMI) (Borkoles, Polman, & Levy, 2010; Einvik et al., 2011; Gilmour & Williams, 2011; Hausteiner et al., 2010; Mommersteeg, Kupper, & Denollet, 2010; L. Williams et al., 2008), and greater alcohol consumption (Consedine, Magai, & Horton, 2005). For example, in a recent study of 3,000 Dutch adults with diabetes, those identified as having the Type D personality (characterised by high inhibition coupled with high negative affect), had poorer dietary management and reduced likelihood of consulting healthcare professionals (Nefs et al., 2015). Furthermore, the Type D personality was independently associated with a 2- to 3-fold increased odds of overall suboptimal health behaviours (combined scores of adherence to medication, diet, exercise, monitoring of blood glucose, inspection of feet, weight maintenance, and alcohol consumption) (Nefs et al., 2015). Additionally, work in other patient groups has found that expressive suppression independently predicts poorer consultation behaviour in patients with chronic heart failure (Pelle, Schiffer, Smith, Widdershoven, & Denollet, 2010) and lower medication adherence among myocardial infarction patients (L. Williams, O'Connor, Grubb, & O'Carroll, 2011). Overall, these findings suggest that links between suppression and health may be due to poorer engagement in health behaviours among those reporting a tendency to suppress emotion.

Trait suppression, pain, and physical symptoms

In addition to poorer health behaviours, trait suppression has been widely investigated in the context of chronic pain disorders and symptom reporting. Compared with healthy controls, participants diagnosed with chronic pain normatively report greater trait suppression (Amir et al., 2000; Arena, Bruno, Rozantine, & Meador, 1997; Hatch et al., 1991; Materazzo, Cathcart, & Pritchard, 2000; Nicholson, Gramling, Ong, & Buenevar, 2003; Sayar, Gulec, & Topbas, 2004; Thomas, Moss-Morris, & Faquhar, 2006). Equally, trait suppression is correlated with greater pain sensitivity in both pain patients (Bruehl, Burns, Chung, Ward, & Johnson, 2002; Burns, Johnson, Mahoney, Devine, & Pawl, 1996; Kerns, Rosenberg, & Jacob, 1994; Middendorp et al., 2010), and pain-free groups (Bruehl et al., 2002; Burns, Bruehl, & Caceres, 2004; Burns, Kubilus, & Bruehl, 2003; Gelkopf, 1997; Janssen, Spinhoven, & Brosschot, 2001). More broadly, trait suppression is negatively associated with general perceived health (Hausteiner et al., 2010), and is positively associated with symptom reporting (Consedine et al., 2005; L. Williams & Wingate, 2012), sleep disturbances (Consedine, Magai, Cohen, & Gillespie, 2002), gastrointestinal, respiratory, and musculoskeletal problems (Vandervoort, Ragland, & Syme, 1996), as well as greater physical limitations, among participants with rheumatoid arthritis, and asthma symptoms in those with asthma (M. A. Russell, Smith, & Smyth, 2016). Thus, in addition to predicting poorer health behaviours, dispositional emotion inhibition is also associated with greater symptomology in a variety of patient and non-patient groups.

Trait suppression and disease risk

Finally, self-reported trait suppression has also been widely studied in the context of more objective health indices, particularly CVD (Everson-Rose & Lewis, 2005; Low, Thurston, & Matthews, 2010). Work testing links between expressive suppression and markers of biological and/or physiological risk show that suppression is associated with poorer outcomes as indexed by blood pressure responsiveness (Mills & Dimsdale, 1993), hypertension (Consedine, Magai, Cohen, et al., 2002), hypercholesterolemia (Hausteiner et al., 2010), inflammation (Appleton, Buka, Loucks, Gilman, & Kubzansky, 2013; Einvik et al., 2011), cardiovascular reactivity (Gross & Levenson, 1997), HRV (Horsten et al., 1999), carotid artery stiffness (Anderson, Metter, Hougaku, & Najjar, 2006), and calculated projected cardiac risk scores (Appleton, Loucks, Buka, & Kubzansky, 2014). For example, in a cross-sectional study of over 1,500 participants, those reporting a combination of high trait suppression and high negative affect indexed a twofold increased risk of metabolic syndrome, independent of lifestyle factors and known confounds (Mommersteeg et al., 2010).

Complementing these data, prospective work indicates that greater trait suppression predicts worse cardiac outcomes. Specifically, higher self-reported suppression prospectively predicts greater four-year risk of incident hypertension (Everson, Goldberg, Kaplan, Julkunen, & Salonen, 1998), carotid atherosclerosis (Julkunen, Salonen, Kaplan, Chesney, & Salonen, 1994; K. A. Matthews, Owens, Kuller, Sutton-Tyrrell, & Jansen-McWilliams, 1998), the development of coronary heart disease (CHD) (Haynes et al., 1980), and greater all-cause, cardiac, and cancer mortality (Chapman, Fiscella, Kawachi, Duberstein, & Muennig, 2013; Graves, Mead, Wang, Liang, & Klag, 1994; Harburg, Julius, Kaciroti, Gleiberman, & Schork, 2003; Haynes et al., 1980). Finally, work in cardiac patient groups has found that trait suppression is associated with impaired health status among patients with chronic heart failure (Pelle et al., 2010) and increased risk of future cardiac events among those with coronary artery disease (Denollet, Gidron, Vrints, & Conraads, 2010).

2.5 Chapter summary and concluding remarks

In summary, the evidence reviewed above demonstrates that self-reported trait suppression predicts poorer health behaviours, greater physical symptomology (in both patient groups and community samples), increased cardiovascular risk, and greater all-cause, cardiac, and cancer mortality. These findings, coupled with evidence that experimentally manipulated expressive suppression elevates sympathetic nervous system activity, while having a detrimental effect on cognitive and social task performance, support the suggestion that trait expressive suppression has adverse consequences for physical health.

Chapter 3 : Limitations of work to date

3.1 Overview: The evidence linking expressive suppression with health is flawed

The previous chapter presented findings from two bodies of work which indicate that expressive suppression is associated with poorer health outcomes. As will become clear however, evidence of links between expressive suppression and health is based on a particular set of designs, samples, data, and theoretical assumptions. As such, the focus of the present chapter is to outline the conceptual and methodological limitations in prior work that undermine confidence in the documented links between expressive suppression and poorer health.

First, the view that expressive suppression is inherently damaging is at odds with evolutionary and functionalist accounts, which interpret expressive suppression as an essential feature of the broader capacity to effectively regulate social signalling. Second, it is argued that although experimentally manipulated suppression produces short-term physiological activation, such reactivity cannot be extrapolated to long-term health consequences. Finally, three limitations inherent in the epidemiological literature linking suppression to poorer health outcomes are highlighted. Specifically, it is suggested that self-reported data display poor generalisability across groups and situations, are prone to reporting biases, and are vulnerable to the influence of third variables that are also implicated in health (e.g., negative affect). In questioning the notion that expressive suppression is necessarily bad for health, or indeed that trait assessments are the best way to measure expressive regulation, this chapter argues that the methodological and conceptual limitations of work to date mean that it cannot be stated with certainty that expressive suppression is associated with worse physical health outcomes.

3.2 Conceptual limitations: Suppression is important (and useful)

Evolutionary accounts position facial expressions as behavioural adaptations, selected for because they helped to address specific problems of survival and adjustment (Nesse, 1990; Owren & Bachorowski, 2001; Tooby & Cosmides, 1990, 2008). Both evolutionary and functionalist frameworks conceptualise facial expressions as low-cost signalling systems (Bergstrom & Lachmann, 1998; Fridlund, 1997). Whereby, rather than being unmitigated readouts of internal emotionality, facial expressions are thought of as social signals that evolved to facilitate the transmission of information between conspecifics, about both the sender, and aspects of the environment (Borghi & Cimatti, 2010; Fridlund, 1991b, 1997, 2014; J. Glaser & Salovey, 1998; Hareli & Hess, 2010; Hareli, Shomrat, & Hess, 2009; Hess et al., 2009; Hess et al., 1995; Hess, Blairy, & Kleck, 2000; Manstead, 1991; Parkinson, 1996; Van Doorn, Heerdink, & Van Kleef, 2012; Van Kleef, De Dreu, & Manstead, 2004a, 2004b). Within this view, the ability to regulate expressivity is adaptive because it allows individuals to control the amount and type of information that is shared with others.

For example, it is thought that facial displays of pride signal elevated status (J. P. Martens, Tracy, & Shariff, 2012), whereas expressions of shame and embarrassment serve appeasement functions, facilitating social resolution following transgressions (Keltner & Anderson, 2000; J. P. Martens et al., 2012). Sad expressions encourage reparatory actions (Blair, 1995), and elicit support from others (Campos, Campos, & Barrett, 1989; Eisenberg et al., 1989), whereas fearful expressions rapidly signal the presence of a threat (Mineka & Cook, 1993). Importantly, although these expressions *may* occur in conjunction with the corresponding feeling state, they do not *necessarily* reflect the presence of that emotion.

More broadly, although there are situations where it might be useful to communicate our internal states to others, there are also circumstances where this would be detrimental to either individual or group interests (Keltner & Buswell, 1997; Provine, 1996). In conditions where food, resource, reputation, or other positive outcomes were at stake (Ekman & Rosenberg, 1997; Mitchell, 1999), it is likely that selective pressures would have favoured the ability to deliberately conceal, manipulate, or substitute facial expressions (Schmidt & Cohn, 2001). Hence, rather than reflexively signalling feeling states, it is thought that the ability to modulate expressive behaviour evolved to allow individuals to navigate the relative costs and benefits of sharing information (Fridlund, 1997; Schmidt & Cohn, 2001).

In addition to hiding expressions that are not adaptive at specific junctures, there are circumstances in which expressive signals are emitted in the absence of the accompanying feeling state. Cultural display rules govern the type and amount of expressivity that is appropriate in any given situation (Ekman, Friesen, & Ellsworth, 1972; Malatesta & Haviland, 1982; Matsumoto, 1990; Mitchell, 1999; Saarni, 1979), and the ability to up- and down- regulate expressivity enables individuals to adhere to display rules regardless of internal feelings. For example, although being greeted by someone with a smile may reflect genuine happiness, their smile may also represent an over-learned signal of positive intent that is socially appropriate in that particular context (Hareli & Hess, 2012).

Similarly, although the expression of positive emotion generally predicts better outcomes (e.g. Davidson, Mostofsky, & Whang, 2010; Hayashi et al., 2016; Kok et al., 2013), there are also times when it is adaptive to suppress positive signals. For example, overt displays of positive emotion are discouraged when winning in competitive contexts, and work in Australian samples has found that participants who suppressed positive expressions when winning were rated more favourably in terms of personality traits than those who openly expressed positive emotion (Kalokerinos, Greenaway, Pedder, & Margetts, 2014). Similarly, when participants were secretly videotaped responding to information that they had won a competition, those who were alone expressed more positive emotion than those who were in a room with other competitors (H. S. Friedman & Miller-Herringer, 1991), perhaps indicating an awareness of the social consequences of unfettered expressivity.

As such, in addition to potential negative consequences of *not* showing the appropriate emotion, there are also potential costs to the uncontrolled or reflexive expression of both positive and negative emotions. Consequently, the *ability* to up- and down-regulate facial displays of emotion to best meet situational demands may be a better way of conceptualising adaptive expressive regulation, however, this view is at odds with the notion that expressive suppression is fundamentally damaging.

3.3 Limitations of experimental studies: There is no 'health' outcome

As outlined in Chapter 2, the suggestion that expressive suppression is maladaptive has been partly based on evidence from experimental work, which reports that expressive suppression leads to greater activation of the cardiovascular system (Demaree, Schmeichel, et al., 2004; Demaree, Schmeichel, et al., 2006; Gross, 1998a; Gross & Levenson, 1993; Gross & Levenson, 1997; Lanzetta et al., 1976; Vaughan & Lanzetta, 1981; Zuckerman et al., 1981). In light of these findings, it has been proposed that the habitual, repeated use of expressive suppression, and (presumably) the resulting physiological activation, has a cumulative, detrimental impact on cardiovascular health (Everson-Rose & Lewis, 2005; Krantz & Manuck, 1984; Manuck & Krantz, 1986; Rozanski et al., 1999).

However, the logic of treating links between expressive suppression and acute cardiovascular activation as evidence that suppression is damaging over time is problematic. Physiological activation does not necessarily damage bodily systems in and of itself; indeed, humans are designed to react to stimuli and then return to homeostasis. As such, momentary elevations in sympathetic arousal cannot be considered a health outcome, and consequently, the assumption that longer term health costs follow repeated instances of suppression is problematic. Hence, although it is implied that repeated or chronic suppression may be deleterious over time (Gross, 1998a), this possibility has not been explicitly tested.

Furthermore, although manipulated suppression appears to produce cognitive and physiological costs, the repeated use of any regulatory strategy should increase expertise and efficiency in implementing that approach, potentially reducing the associated costs due to practice effects (e.g. Walker, O'Connor, & Schaefer, 2011). As such, those with a greater tendency to suppress emotion, may not exhibit the same pattern of negative consequences. However, because experimental studies do not capture individual differences in the degree to which people actually engage in any particular strategy, or their ability to do so, work in this tradition does not tell us whether the people that frequently suppress emotion experience the same adverse consequences. Indeed, as is outlined in the following section, work increasingly suggests that the costs associated with expressive suppression are not uniformly evident across individuals and situations (e.g. Burns, Holly, et al., 2008; Walker et al., 2011). This consideration, coupled with the earlier argument that short-term reactivity cannot be extrapolated to longer term health outcomes, means that experimental studies provide comparatively modest evidence for the claim that dispositional suppression has a negative impact on physical health.

3.4 Limitations of self-reported trait suppression

The second major area of work suggesting that suppression predicts poorer health outcomes is based on self-reported assessments of habitual trait suppression. However, self-reported assessments have three key limitations which collectively call into question the notion that suppression is necessarily unhealthy. First, accumulating evidence for the role of contextual factors in moderating the links between suppression and outcomes imply that links cannot be generalised across groups or situations (see Aldao, 2013 for a review). Second, because people are not equally willing or able to accurately report on typical regulatory behaviours, self-reports are likely to be biased and should be interpreted with caution. Finally, because self-reported regulation captures shared variance with other constructs (notably negative affect), the observed links between trait suppression and outcomes may be attributable to third variable confounds. Taken together, these considerations suggest that negative associations between expressive suppression and physical health outcomes cannot be stated with any real certainty.

Limitations of self-reported traits; the role of context

This initial section reviews evidence suggesting that factors pertaining to the individual, the emotion, and the regulatory goals all moderate the links between trait regulation and outcomes. Such findings suggest a lack of generalisability in the suppression-health relationship, and indicate that the utility of any regulatory strategy will be influenced by aspects of the wider context. Consequently, the ability to flexibly implement the most suitable regulatory strategy in any given situation may be a better way of thinking about 'adaptive' regulation. However, as will be discussed, a 'regulatory flexibility' construct cannot be reliably assessed using self-reported trait measures.

Accruing evidence suggests that the relationship between suppression and outcomes is moderated by factors such as culture and ethnicity (Consedine, Magai, Cohen, et al., 2002; Consedine et al., 2005; Soto, Perez, Kim, Lee, & Minnick, 2011), personality (Burns, Holly, et al., 2008), age (Brockman, Ciarrochi, Parker, & Kashdan, 2016; Emery & Hess, 2011), and gender (M. A. Russell et al., 2016). For example, the inhibition of anger appears to be more damaging for men than women (Burns, 1995; M. A. Russell et al., 2016; Vögele, Jarvis, & Cheeseman, 1997), and in younger, but not older, samples (Emery & Hess, 2011). Furthermore, suppression does not predict negative outcomes in Asian (Butler et al., 2007; Soto et al., 2011; Wei, Su, Carrera, Lin, & Yi, 2013) or Eastern European groups (Consedine et al., 2005), suggesting that the adverse consequences of expressive suppression may be less evident in cultures or situations that call for emotional restraint (Soto et al., 2011).

In addition to demographic moderators, evidence suggests that individual regulatory *preferences* influence links between suppression and outcomes, whereby suppression may only be damaging when it is at odds with a person's preferred regulatory style (Burns, Holly, et al., 2008). For example, in a study of pain patients, suppressing anger had the strongest negative impact on muscle tension among those who reported typically expressing their anger (Burns, Holly, et al., 2008). Similarly, any deleterious effects of suppressing emotion may be mitigated among those who habitually suppress expressivity. For example, alexithymia is positively correlated with trait suppression (Swart, Kortekaas, & Aleman, 2009), and work using event-related potentials suggests that individuals high in alexithymia are more efficient at implementing expressive suppression (Walker et al., 2011), potentially increasing the likelihood of effective suppression, whilst decreasing any potential costs.

Furthermore, characteristics of the emotion being regulated also appear to moderate links between regulatory strategies and outcomes (Troy, Shallcross, & Mauss, 2013). Specifically, qualities such as intensity (Sheppes et al., 2014) and controllability (Troy et al., 2013), may determine the adaptive utility of various regulatory strategies. For instance, although cognitive reappraisal appears to be an appropriate strategy when emotional intensity is low, strategies that allow for disengagement (e.g. distraction) appear to be more adaptive when emotions are more intense (Sheppes et al., 2014). Notably, although cognitive reappraisal is generally lauded as adaptive – in part because it alters the emotional experience – there are times when adjusting the underlying emotion may not be the best course of action. For example, although cognitive reappraisal predicts lower depression when stressors cannot be controlled, it predicts higher depression when applied to controllable stressors (Troy et al., 2013). In such circumstances, strategies that keep the underlying emotion and its motivating features intact (such as expressive suppression), may lead to better outcomes (e.g. Bonanno & Keltner, 1997; Bonanno, Keltner, Holen, & Horowitz, 1995), potentially by motivating goal directed behaviour towards addressing problems in the environment, rather than adjusting the underlying feeling state (Panno, Lauriola, & Figner, 2013).

Collectively, this work indicates that the utility of any given regulatory strategy is influenced by demographic, personality, and environmental factors, as well as the nature of the emotional experience and the regulatory goals of the individual. As such, although there are times when strategies such as cognitive reappraisal are clearly useful, there are also times when alternative strategies such as expressive suppression may be of benefit (e.g. Bonanno & Keltner, 1997; Bonanno et al., 1995). More to the point, if no single strategy is uniformly adaptive or maladaptive, then the ability to flexibly adjust strategy use in accordance with situational factors, is likely to be associated with better outcomes. If this is the case, then it is readily apparent that trait metrics, which are based on the self-reported *frequency* of strategy use, and amalgamate strategy use across multiple contexts, are poorly equipped to capture the flexible nature of adaptive expressive regulation.

Limitations of self-reported traits; the risk of reporting biases

In addition to difficulties regarding contextual moderation and generalisability, evidence for links between trait suppression and poorer outcomes is undermined by differences in the degree to which people are aware of both their emotions, and the strategies that they use to regulate them (Snyder, 1974). Using the examples of alexithymia and repressive coping, the present section argues that a multitude of factors influence the ability to report on habitual patterns of regulation. This has the implication that the evidence base for treating suppression as reliably associated with worse health outcomes is weaker than might be thought.

Although there are numerous personality traits that might influence the level of insight that people have regarding their habitual regulatory behaviour, alexithymia and repressive coping offer two such examples. Depending on estimates, repressive coping is apparent in 12-60% of the population, increases across the lifespan (Erskine et al., 2015), and is characterised by an impaired ability to detect one's own negative emotions (Myers & Brewin, 1996; Weinberger, Schwartz, & Davidson, 1979). Likewise, alexithymia is characterised by difficulties identifying, describing and labelling emotions (Franz, Schaefer, & Schneider, 2003; Franz, Schaefer, Schneider, Sitte, & Bachor, 2004; Lumley, 2004), with moderate to high levels of alexithymia evident in approximately 60% of community-dwelling adults (McGillivray, Becerra, & Harms, 2016). Both repressive coping and alexithymia are likely to limit the degree of insight that people have into their own regulatory behaviour (Lumley, 2000, 2004; Lumley, Gustavson, Partridge, & Labouvie-Vief, 2005), meaning that social desirability and response sets are likely to influence questionnaire responding among people with these traits (Podsakoff, MacKenzie, & Podsakoff, 2012). As such, the high prevalence of alexithymia and repressive coping in the community undermines the reliability of self-reports of regulatory behaviour.

Support for the argument that self-reported assessments are problematic is evident in studies using within-person designs, such as daily diary and ecological momentary assessment (EMA) methods (e.g. Brose, Voelkle, Lövdén, Lindenberger, & Schmiedek, 2015; Kashdan & Nezlek, 2012; Nezlek & Kuppens, 2008). These studies demonstrate that self-reported trait suppression is either not associated with ratings of daily expressive suppression, or is only modestly correlated. For example, in a study of 300 women with fibromyalgia, baseline trait suppression was only weakly associated with daily reported suppression ($r = .22$, $p < .05$) (Middendorp et al., 2010). In a similar vein, another study found that although trait suppression was associated with lower PA and higher NA, it was not associated with daily reported suppression (Brockman et al., 2016). Thus, self-reported regulatory tendencies may be more closely related to trait affect than actual regulatory behaviour, a point that is addressed in further detail in the final section of this chapter.

In addition to reporting biases, there is uncertainty regarding the precise constituents of expressive suppression that are being indexed by self-report metrics. Although some investigators define expressive suppression as the inhibition of facial expressivity (as in studies based on manipulated suppression), self-reports of suppression typically capture a broader range of behavioural and social dispositions. Such measures typically fail to discriminate between *experiential* suppression and *expressive* suppression. This then leads to uncertainty regarding whether links between suppression and health are specific to the modulation of *facial expressions* or whether they reflect the influence of more general behavioural and social tendencies.

For example, much of the evidence linking expressive suppression to pain has been based on the State-Trait Anger Expression Inventory (STAIX) (Forgays, Forgays, & Spielberger, 1997; C. D. Spielberger et al., 1985). Although several items capture the tendency to suppress the visible expression of emotion, others, such as '*harbour grudges*', ' *withdraw from people*', and *'secretly critical of others'* index coping strategies, social avoidance, and hostility, rather than expressive suppression *per se*.

This operationalisation issue is also apparent in two highly influential studies linking expressive regulation with cardiac disease risk. One study used a single item to capture the tendency to suppress emotion (Haynes et al., 1980), while the other selected 37 items from the revised Minnesota Multiphasic Personality Inventory (MMPI-2) to assess the general tendency to regulate emotion (Kubzansky et al., 2011). Hence, although there are numerous studies linking self-reported trait suppression with health outcomes, the precise meaning of the term "suppression" is frequently unclear.

Limitations of self-reported traits; evidence for 3rd variables

Compounding difficulties regarding the measurement and operationalisation of trait expressive suppression and issues with generalisability, is the fact that self-reported expressive regulation is almost invariably conflated with third variable confounds; notably trait negative affect (NA). This section first presents evidence showing that trait suppression is reliably associated with indices of NA, before summarising empirical support for the mediating role of NA in the link between suppression and outcomes. In highlighting the difficulties in disentangling trait suppression from general NA, it is suggested that trait suppression may partially (or only) predict health outcomes due to shared variance with negative emotionality.

As mentioned, the tendency to report greater suppression has been reliably associated with greater negative emotionality, including general NA (Brans, Koval, Verduyn, Lim, & Kuppens, 2013; Brotheridge & Grandey, 2002), stress, avoidant coping (L. Williams & Wingate, 2012), neuroticism (Richards & Gross, 2000; L. Williams et al., 2008), rumination (Gross & John, 2003), anger (Martin & Watson, 1997; M. A. Russell et al., 2016), depression (Franchow & Suchy, 2015; Haga et al., 2009), anxiety (Nefs et al., 2015), and distress in both the general population (Mols & Denollet, 2010b) and patient groups (Al-Ruzzeh et al., 2005; Mols & Denollet, 2010a; Schiffer et al., 2005). In turn, aspects of negative emotionality are robustly associated with health outcomes via physiological, cognitive, and behavioural pathways (for reviews see Consedine & Moskowitz, 2007; Mayne, 1999). Therefore, if people reporting high suppression also have greater NA, negative emotionality may be responsible for the apparent links between expressive suppression and poorer health.

Despite this possibility, few studies investigating the relationships between expressive suppression and outcomes control for negative emotionality (e.g. Chapman et al., 2013; Coté & Morgan, 2002), or control is inconsistent. For example, although one recent report documenting a positive link between suppression and inflammation did control for depression (Appleton, Buka, Loucks, Gilman, et al., 2013), another report using the same sample, linking suppression with cardiac risk did not (Appleton et al., 2014).

Perhaps more to the point, when studies *do* control for NA it is often found that a substantial proportion of the variance in links between suppression and health can be attributed to aspects of negative emotionality (e.g. Bruehl, Chung, & Burns, 2003;

Bruehl, Chung, Burns, & Biridepalli, 2003; Nicholson et al., 2003). For example, although the tendency to suppress anger is associated with greater reported pain outcomes (Burns et al., 2012; Quartana & Burns, 2007; Quartana et al., 2007), the most consistent links between suppression and pain occur when pain assessments are based on the emotional constituents of pain (Bruehl et al., 2002; Bruehl, Chung, & Burns, 2003; Bruehl, Chung, Burns, et al., 2003; Burns, Quartana, Gilliam, et al., 2008), and links between suppression and pain diminish when controlling for depression (Bruehl, Chung, & Burns, 2003; Bruehl, Chung, Burns, et al., 2003; Nicholson et al., 2003). This suggests that negative emotionality (in this case, depression), and the tendency to appraise pain in emotional terms, may underlie the links between measures of trait suppression and pain (Burns, Quartana, & Bruehl, 2008).

In addition to findings in pain samples, recent work in patients with asthma and rheumatoid arthritis indicates that trait suppression is associated with greater anger, which in turn predicts higher symptom reporting (M. A. Russell et al., 2016). Importantly in this case, substituting trait suppression for anxiety produced similar results, interpreted as evidence that the effects of suppression may be in-part due to a general propensity towards NA (M. A. Russell et al., 2016). Other work also shows that the links between suppression and inflammation diminish when controlling for depression and other confounds (smoking, education and BMI) (Appleton, Buka, Loucks, Gilman, et al., 2013). Finally, although the interaction of NA and expressive inhibition is associated with worse cardiac outcomes even when controlling for depression (E. J. Martens, Mols, Burg, & Denollet, 2010), inhibition alone is not a strong predictor of health (e.g. Nefs et al., 2015), and patients high in trait inhibition in the absence of NA do not appear to be at increased cardiac risk (Denollet, Pedersen, Vrints, & Conraads, 2013).

Consequently , if measures of expressive suppression/inhibition are involuntarily capturing dispositional NA (or other confounds), then trait suppression may only be related to health to the degree that it shares variance with negative emotionality (Burns, Quartana, Gilliam, et al., 2008). If substantiated, this interpretation further undermines one of the two key empirical "pillars" supporting the notion that the suppression of emotion is unhealthy.

3.5 Chapter summary and concluding remarks

This chapter has presented evidence from three key areas, collectively questioning the notion that expressive suppression is necessarily bad or, indeed, that trait suppression is the correct operationalisation of emotion regulation as it pertains to health. First, conceptual limitations were outlined by highlighting the discrepancy between the notion that suppression is necessarily harmful, and evolutionary and functionalist perspectives which view the ability to regulate expressive responding as an important skill, necessary for daily social interactions. Second, this conceptual point was reinforced by a critique of experimental work in which it was suggested that although manipulated expressive regulation is associated with indices of physiological and cognitive reactivity, such metrics cannot be extrapolated to imply longer term health outcomes. Third, it was argued that links between trait suppression and outcomes cannot be generalised across people, situations, or emotions, and that self-reported traits are limited by reporting biases and co-variation with third variable confounds, particularly NA. As such, despite the widely held belief that expressive suppression is damaging to health, robust and unambiguous evidence to support this claim is more modest than might be thought.

Chapter 4 : An argument for the assessment of skills

4.1 Overview

The conceptual and methodological concerns noted in the prior chapter demonstrate that it cannot be stated with certainty that expressive suppression causes poorer health outcomes. In taking initial steps to explain how a different approach addresses some of these limitations, the current chapter presents a rationale for adopting a *skills*-based approach to the conceptualisation and measurement of expressive regulation.

First, to provide a theoretical framework highlighting the need to assess emotion regulatory skills, a tripartite model is described, which characterises expressive regulation in terms of traits, knowledge, and skills. Using this model it is suggested that although work has primarily focused on traits, expressive regulatory knowledge and skills may also show links to physical health. Second, this chapter suggests that a focus on regulatory skills has conceptual advantages and is more closely aligned with current evolutionary, functionalist, and developmental accounts. Third, it is argued that because skills can be objectively assessed, such an approach addresses many of the methodological concerns pertinent to trait measures, particularly reporting biases, and method-related covariation with other self-reported, trait variables. Relatedly, because skills are readily assessed using laboratory paradigms which keep contextual moderators (such as the emotion's elicitor, the regulatory target, or the intensity of the emotion) constant, such an approach is less vulnerable to contextual moderation, another area in which trait characterisations of expressive regulation struggle. Finally, in reviewing the small body of empirical work that has investigated links between expressive regulatory skills and outcomes, this chapter demonstrates that not only do skills-based assessments predict outcomes, but also that the overall pattern of findings is generally at odds with the suggestion that expressive suppression is damaging for health. Instead, evidence suggests that the ability to both enhance and suppress the expression of emotion predicts better outcomes.

Overall, in presenting a theoretical account of emotion regulation that incorporates regulatory traits, knowledge, and skills, and in demonstrating the conceptual and methodological advantages in objective tests of regulatory abilities, this chapter argues that the assessment of skills is potentially better suited to examining the links between expressive regulation and health, than trait-based measurements. It thus provides a rationale for adopting the skills-based approach to the measurement of expressive regulation that characterises the empirical work in this thesis.

4.2 The tripartite model of emotion regulation: Traits, knowledge and skills

The tripartite model of emotion regulation (Mikolajczak, 2010; Mikolajczak et al., 2015) suggests that rather than focusing exclusively on traits, emotion regulatory knowledge and skills are also necessary features of successful or adaptive emotion regulation. Within this model, regulatory traits reflect habitual patterns of regulation, knowledge encapsulates how much a person knows or understands about their own and others' emotions, and skills represent the ability to successfully implement a particular regulatory strategy (Mikolajczak, 2010). For example, a person may regularly play social football (trait), and may know a lot about football rules and regulations (knowledge), but they may not be particularly skilled at playing the game (skill). Likewise, a person may generally express emotions in a particular manner. However, the way in which they regulate expressivity will also be influenced by their knowledge of appropriate behaviour, and their capacity to successfully express or inhibit expressivity in the moment. As such, while traits, knowledge, and skills are related, they are also distinct, and although prior work has predominantly focused on regulatory traits (see Chapter 2), successful regulation should also reflect individual differences in knowledge and skills.

4.3 Conceptual advantages of a skills-based approach

In addition to addressing an empirical gap in the literature, investigating whether expressive regulatory skills and knowledge also predict health has conceptual advantages over trait assessments. This is because such an approach is more consistent with functionalist, evolutionary, and developmental accounts, which view facial expressions as signals used to transmit information to others (Consedine & Moskowitz, 2007; Nesse, 1990; Tooby & Cosmides, 1990, 2008).

As was discussed in Chapter 3, evolutionary accounts view the *ability* to regulate expressive responding as an adaptation, selected for because it enabled individuals to modulate the amount and type of personal and situational information that was shared with others (Fridlund, 1997; Schmidt & Cohn, 2001). If we accept this likelihood, then both knowledge regarding appropriate expressive behaviour and the ability to regulate facial signals in a manner that meets situational demands and furthers goal attainment should be characterised as maximally adaptive. Objective tests of skill and knowledge appear better equipped to address these features than do trait assessments of habitual behaviour, which by their nature are insensitive to contextual features.

In addition to being more consistent with functionalist and evolutionary accounts, conceptualising expressive regulation in terms of skills is also compatible with developmental theory and research (e.g. Fox & Calkins, 2003). Developmental work considers expressive regulation to be a skill that develops incrementally over time as a series of developmental milestones (for reviews see Harris, 1989; Thompson, 1991) (Demos, 1986). For example, at birth expressive behaviours function to secure caregiving through crying (Bolwby, 1969), smiling, and vocalising in a manner that reinforces caregiver attention (Emde, Gaensbauer, & Harmon, 1976). Over time, infants develop the ability to regulate their own emotions (such as by shifting gaze) (Derryberry & Rothbart, 1988), and become increasingly skilled at regulating expressivity in a manner that influences the behaviour of others (Denham et al., 2003; Malatesta-Magai et al., 1994; Malatesta & Wilson, 1988). This progression occurs in tandem with social, cognitive, and neural development (for a review see Izard & Malatesta, 1987), with greater ability to regulate the expression of emotion, predicting better psychosocial outcomes in children and infants (Custrini & Feldman, 1989; Denham et al., 2003; Denham, McKinley, Couchoud, & Holt, 1990; Zuckerman & Przewuzman, 1979).

As importantly, and perhaps because self-report is not a viable measurement paradigm in early life samples, studies in the developmental tradition have relied almost exclusively on objective, behavioural assessments of emotion regulation. Indeed, the switch to self-reported trait approaches when examining adolescent and adult samples appears to be more strongly motivated by methodological convenience than theoretical considerations; self-reports require fewer resources and less inference than behavioural coding systems. However, findings from the developmental literature that objectively assessed regulatory abilities are important predictors of outcomes (Denham et al., 2003; Denham et al., 1990) offer further support for the use of a skills-based approach in the assessment of expressive regulation.

4.4 Methodological advantages of a skills-based approach

It is increasingly apparent that the assessment of skills is more consistent with current emotion regulatory theory, as well as with evolutionary and developmental considerations. In extending this general logic and rationale, the present section identifies three ways in which the assessment of skills is *methodologically* advantaged over prior work. Specifically, it is argued that a skills-based approach extends laboratory-based studies of manipulated expression by allowing for the investigation of health *outcomes*, while concurrently avoiding the issues associated with self-reported traits, and facilitating the more controlled and transparent evaluation of contextual moderators.

Advantages over experimentally manipulated regulation

As outlined in the previous chapters, the view that expressive suppression is detrimental to physical health has been largely derived from studies in which participants are randomised to engage in particular regulatory strategies, while short-term cognitive (Richards & Gross, 2000), physiological, affective (Gross, 1998a; Gross & Levenson, 1993; Gross & Levenson, 1997), and social consequences (Butler et al., 2003) are assessed. However, because short-term reactions may not equate to longer-term outcomes, such designs do not identify whether individual differences in expressive regulation have a cumulative impact on health.

In addressing this limitation, measuring the *ability* to successfully implement a particular regulatory strategy, generates an objective, individual-differences metric, which can then be linked to indices of health and health behaviour, using both cross sectional and prospective designs. Doing so retains the benefits of a controlled laboratory paradigm, while allowing for the investigation of whether individual differences in expressive regulation are associated with physical health outcomes such as current health status and/or future disease risk.

Advantages over self-reported traits

In addition to advantages over between-group experimental designs, a second methodological advantage is that objectively assessed skills ameliorate many of the limitations of self-reported trait measurements. As noted, self-reported expressive regulation is frequently conflated with third variables (Burns, Quartana, & Bruehl, 2008) and is only weakly correlated with actual regulatory behaviour, if at all (Bruehl, Liu, Burns, Chont, & Jamison, 2012; Middendorp et al., 2010). Discrepancies of this kind, coupled with evidence that people differ in both their ability and motivation to report accurately on their own emotions and expressive regulatory tendencies (e.g. Schwerdtfeger & Kohlmann, 2004), challenge the reliability and validity of self-reported trait regulation.

By contrast, both knowledge regarding appropriate regulatory behaviour, and skill in implementing particular regulatory strategies can be assessed using objective, performance-based metrics. Although motivational considerations are possible, reporting biases are less relevant in performance-based tests, and such measures are less vulnerable to the influence of personality factors such as NA. In obviating the need for self-report, a skills-based approach offers a means of assessing individual differences in expressive regulation in a less confound-prone manner.

Furthermore, as was noted in Chapter 3, accumulating evidence that both individual and contextual factors moderate the links between trait expressive regulation and outcomes, suggests that when it comes to healthy emotion expressivity, one size does not fit all, and alternative considerations of what 'counts' as adaptive expressive regulation are needed (Bonanno & Burton, 2013). Evidence that the utility of any given strategy varies across people and situations (Aldao, 2013; Gross, 2015) is fundamentally at odds with the view that specific strategies (such as suppression) are uniformly adaptive or maladaptive (Bonanno & Burton, 2013). Rather, because situational factors influence the extent to which regulatory strategies are beneficial (or not), the ability to *adjust* expressive responding in a manner that meets situational demands or furthers the goals of the individual should be most adaptive (Bonanno & Burton, 2013). However, this possibility cannot be explored with trait assessments, which aggregate across situations.

Conversely, skills-based assessments do not assume stable, habitual patterns of regulation are occurring regardless of context, and the objective assessment of skills allows for experimental control over contextual factors (such as systematically varying regulatory targets or the valence and intensity of eliciting stimuli). Thus, a further methodological advantage of a skills-based approach is that it is more consistent with evidence that the utility of enhancing or suppressing expressive responding varies according to context (e.g. Aldao, 2013; Gross, 2015).

4.5 Empirical support for a skills-based approach

In further developing the idea that a skills-based approach offers a useful supplement to trait assessments, this final section summarises prior work that has empirically investigated links between expressive regulatory skills and outcomes. Although this literature is small and mostly based in mental (rather than physical) health, it demonstrates that objective assessments of the *ability* to regulate expressivity, predicts important cognitive, psychological, and physical outcomes.

Empirical support for adopting a skills-based approach initially came from the coping literature, which converged on a view that rather than any single coping strategy being uniformly adaptive or maladaptive, people that used a range of strategies, and altered strategy use in response to situational variation, had better psychological adjustment (Cheng, 2001; Galatzer-Levy, Burton, & Bonanno, 2012; Gall, Evans, & Bellerose, 2000; Gall, Guirguis-Younger, Charbonneau, & Florack, 2009). This led to the suggestion that the same principle could be applied to expressive regulation. Thus, it was proposed that, rather than any single regulatory strategy being universally beneficial or harmful, the ability to be flexible, and up- and down-regulate expressive responding in accordance with situational demands should predict better adjustment (Bonanno et al., 2004).

To test this possibility, a within-subjects paradigm was developed, in which participants were video recorded while enhancing and suppressing facial expressions in response to emotionally evocative stimuli (Bonanno et al., 2004; D. C. Jackson, Malmstadt, Larson, & Davidson, 2000). Facial expressions were then scored for the magnitude of expressivity, to generate estimates of the ability to up- and down-regulate expressive responding (Bonanno et al., 2004). Using this paradigm, an initial study among New York College students found that a greater ability to both enhance *and* suppress facial expressivity prospectively predicted better self-reported adjustment over a 2-year period. Further, a combination of these two scores, indexing overall expressive *flexibility*, was a stronger predictor of lower distress than either the ability to enhance or suppress expressivity alone (Bonanno et al., 2004).

This initial foray into the predictive utility of skill was soon extended beyond self-reported wellbeing, with subsequent studies demonstrating that greater ability to regulate the expression of emotion predicted better executive functioning, indexed by higher verbal fluency (Gyurak, Goodkind, Kramer, Miller, & Levenson, 2012; Gyurak et al., 2009), greater resilience to trauma (Levy-Gigi et al., 2016; Orcutt, Bonanno, Hannan, & Miron, 2014) and peer-reports of positive psychological adjustment (Westphal et al., 2010). Similarly, deficits in expressive flexibility were found to predict poorer psychological adaptation, and slower recovery from bereavement (Gupta & Bonanno, 2011).

In addition to cognitive and psychosocial outcomes, objective tests of regulatory capacity (Demaree, Pu, Robinson, Schmeichel, & Everhart, 2006; Demaree, Robinson, Everhart, & Schmeichel, 2004), as well as the perceived ability to regulate (Berna, Ott, & Nandrino, 2014; D. P. Williams et al., 2015), have also been associated with higher cardiac vagal tone, indicative of healthier autonomic functioning. Finally, both psychologist-reports of regulatory difficulties (Appleton, Loucks, Buka, Rimm, & Kubzansky, 2013; Potijk, Janszky, Reijneveld, & Falkstedt, 2016), and self-reported deficits in regulatory capacity (Kubzansky et al., 2011; Vlachaki & Maridaki-Kassotaki, 2013) appear to prospectively predict coronary heart disease (CHD).

Despite representing a useful start, evidence of links to *physical* health parameters is limited to work based on self-reports (e.g. Kubzansky et al., 2011) or psychologist-reports (e.g. Appleton, Loucks, et al., 2013; Potijk et al., 2016) of regulatory abilities. Studies are yet to test whether objectively assessed skill-based metrics might also be associated with physical health outcomes. Given the discrepancy between data in mental health (above) which suggest that the ability to suppress expressivity predicts *better* psychosocial outcomes, and findings in physical health suggesting that suppression is deleterious, investigating the links between ability-tests of expressive regulatory skill and physical health outcomes is warranted.

4.6 Chapter summary and concluding remarks

The present chapter opened with a conceptual model describing expressive regulation as encompassing not only traits, but also regulatory knowledge and skills. It was then suggested that objective performance-based-tests of regulatory knowledge and skills are more consistent with theoretical accounts of expressive regulation, and address the limitations of self-reported trait assessments. Early data suggest that skills predict better outcomes, although studies have predominantly assessed mental rather than physical health. Together, these considerations suggest that a skills-based approach to the assessment of emotion regulation is both methodologically and conceptually advantageous, therefore providing a strong rationale for the investigation of links between objective assessments of the *ability* to regulate the expression of emotion, and physical health outcomes.

Chapter 5 : The Research Questions

5.1 Summary of prior work and the rationale for the present thesis

Although conventional wisdom holds that inhibiting the expression of emotion has a detrimental impact on physical health, the evidence base supporting this claim is surprisingly meagre, and studies are undermined by conceptual and methodological limitations. As has been discussed, the suggestion that expressive suppression is health deleterious is at odds with functionalist and developmental reasoning, which both suggest that the ability to up- and down regulate expressivity is a skill, which allows individuals to exert control over their social environment (Hareli & Hess, 2012). Methodologically, experimental links between suppression and physiological activation cannot be extrapolated to longer-term physical health outcomes, and self-reports of expressive regulation are limited by reporting biases and potential third variable confounds. Furthermore, evidence for the role of contextual moderation in the links between suppression and outcomes means that findings cannot be generalised across people or situations.

Indeed, evidence for contextual moderation indicates that the ability to flexibly regulate expressivity in line with personal goals and environmental demands may be a better way of conceptualising adaptive expressive regulation (for reviews see Aldao, 2013; Bonanno & Burton, 2013; Consedine, Magai, & Bonanno, 2002; Gross, 2015). Not only is such an approach more consistent with current theoretical accounts, but because skills can be assessed using objective, performance-based tests, adopting a skills-based approach has several methodological advantages.

However, although a number of studies have investigated whether skill-based metrics predict outcomes, this body of work remains in its infancy, and is restricted in several ways. First, despite skills-based operationalisations being well-suited to objective assessments, many studies continue to rely on self-reported ability metrics, which are vulnerable to the same biases and covariation issues as trait measures (see Chapter 3). Second, although several studies have documented links between expressive regulation and cardiac vagal tone (Demaree, Robinson, et al., 2004; Demaree, Schmeichel, et al., 2006), the majority of work has focused on mental health outcomes (Bonanno & Burton, 2013; Bonanno et al., 2004; Galatzer-Levy et al., 2012; Gupta & Bonanno, 2011; Levy-Gigi et al., 2016; Rodin et al., 2017; Westphal et al., 2010), and potential links to physical health outcomes beyond HRV have not been examined. Finally, work that has used performance-based tests (e.g. Bonanno et al., 2004; Westphal et al., 2010) has focused on the magnitude of broad, valence-based (positive-negative) expressivity, rather than testing the ability to control the expression of specific, discrete emotions. Given that specific expressions are thought to serve particular functions within our social environment (e.g. Fischer, Becker, & Veenstra, 2012; Fischer & Roseman, 2007; Keltner, 1995), a more nuanced, discrete-emotions approach to the assessment of expressive regulatory skills appears to be warranted.

5.2 The research questions

In addressing these limitations the empirical work comprising this thesis tests whether the objectively assessed ability to regulate the expression of emotion is associated with physical health outcomes. Although each published or submitted empirical report includes a rationale for the more specific questions and hypotheses it contains, the overall program of doctoral study was designed to address three overarching questions; (1) Do objective, ability-based tests of expressive regulatory knowledge and skills predict physical health outcomes, (2) what types of health outcomes are most consistently associated with expressive regulatory knowledge and skills, and (3) which skills-based operationalisations are most closely associated with physical health (e.g., enhancing versus suppressing versus general flexibility, as well as skill in signalling specific emotions).

5.3 Summary of empirical work presented in this thesis

These questions were examined across four empirical reports, derived from three laboratory studies. Based on the tripartite model (Chapter 4), the three studies are characterised by the multi-modal assessment of emotion regulatory traits, knowledge, and skills, while health outcomes were assessed in terms of both self-reported physical health and more objective indices of physiological functioning. In brief, Study 1 was designed to test whether the ability to up- and down-regulate expressions of joy, sadness, and anger in response to film stimuli would predict self-reported physical health outcomes and more objective indices of autonomic flexibility, indexed by HRV. Study 2 then tested whether a more portable and rapid means of assessing expressive skill also predicted outcomes. This study was used to produce two reports, the first testing whether HRV was associated with the ability to facially signal specific discrete emotions, and the second, testing whether the ability to signal specific emotions was associated with concentrations of circulating immunoregulatory molecules, along with self-reported physical and psychological wellbeing. This report also tested for links between emotional knowledge and outcomes. Finally, Study 3 extended the clinical relevance of this thesis by testing whether the ability to signal positive emotion was associated with projected 5- and 10-year CVD risk in a community sample. Across the remainder of this thesis each of these reports are presented as separate chapters, before a general discussion examines findings from across these studies in terms of the specific research questions outlined above.

Chapter 6 : Does the ability to regulate different emotions predict different health outcomes?

6.1 Preface

Although it is widely thought that suppressing the outward expression of emotion has a detrimental impact on physical health, conceptual and methodological limitations restrict confidence in this notion. Commensurately, there is a growing consensus that rather than trait-based measures, assessments of the ability to flexibly adjust facial expressivity are more consistent with current theory. Moreover, because such measures permit objective assessment, they are less prone to reporting issues. However, although prior work has demonstrated that skill-based metrics are associated with better outcomes in terms of executive functioning (Gyurak et al., 2012; Gyurak et al., 2009), cardiac vagal tone (Demaree, Robinson, et al., 2004) and psychological adjustment (Bonanno et al., 2004; Gupta & Bonanno, 2011; Levy-Gigi et al., 2016), this body of work is limited in several ways.

First, the possibility that objectively assessed regulatory skills also predict *physical* health outcomes has not yet been tested. Despite this, there is good reason to expect that skill-based assessments will predict physical health. Not only are skills positively associated with psychological adjustment (Bonanno et al., 2004; Gupta & Bonanno, 2011; Levy-Gigi et al., 2016), an established predictor of physical health (Boehm & Kubzansky, 2012; Crowell, Puzia, & Yaptangco, 2015; Gallo et al., 2014), but evidence also suggests that *self-reported* skills predict physical health outcomes (e.g. Gratz et al., 2016; Kubzansky et al., 2011). However, regulatory abilities can be objectively assessed using performance-based metrics, which offer an improvement over self-reported ability measures (see Chapter 3). Consequently, an important step in further understanding the links between emotion regulation and physical health lies in identifying whether objective skill-based assessments are associated with physical health outcomes. To this end, the current chapter presents an initial test of whether the ability to flexibly regulate the expression of emotion is associated with symptom interference and HRV.

A second limitation of work testing links between skills and outcomes is that studies have typically operationalised expressive skill in terms of the *magnitude* of emotion expressed, without considering the accuracy of expressions. As was discussed in Chapter 3, discrete emotions serve distinct signalling functions (e.g. Keltner & Buswell, 1997), and the ability to signal *specific* emotions is integral in transmitting meaningful information. As in the distinction between volume and fidelity, increasing or decreasing the magnitude (or volume) of emotion does not necessarily translate into a clearer expressive signal. For example, although expressions of sadness, anger, fear, and contempt can all be classified as 'negative', each of these expressions transmits a distinct (and potentially opposing) message, thus the ability to accurately express *specific* emotions is critical to signalling the intended information. Likewise, regardless of magnitude, poor accuracy may lead to the wrong 'message' being communicated, thus undermining the functional utility of emotional expressions, with the potential for adverse psychosocial consequences. In addressing this consideration, rather than assessing the magnitude of overall positive/negative expressivity, the present report tests whether the ability to accurately signal specific emotions; sadness, joy, and anger, is associated with physical health outcomes.

Third, in addition to operationalising skills in terms of expressive accuracy, one further reason to move away from valence-based assessment and towards a discrete emotions paradigm is that potential links between expressive skills and health may not be uniform across distinct emotions. Because the normative social consequences of discrete signals vary (Fridlund, 2014; Markus & Kitayama, 1991; Oatley & Jenkins, 1992), some emotions may be more closely related to physical health outcomes than others. For example, the outward expression of anger is frequently associated with adverse social consequences (Haukkala, Konttinen, Laatikainen, Kawachi, & Uutela, 2010; Kitayama et al., 2015), thus, difficulties regulating the expression of anger may have a stronger impact on physical health than difficulties regulating the expression of sadness, which functions to increase available social support (Blair, 1995; Campos et al., 1989; Eisenberg et al., 1989). However, because valence-based assessments of positive/negative expressivity obscure potential emotion-specific links between expressive skills and health, this possibility is yet to be tested. As such, the current chapter presents an empirical report based on a more fine-grained approach to the assessment of expressive regulatory skills, wherein the ability to up- and down regulate expressions of sadness, anger, and joy are assessed, along with their potential links to physical health outcomes.

In considering which physical health outcomes to include, we elected to initially examine links between expressive regulatory skills and both self-reported symptom interference and HRV. HRV was selected because, in addition to being increasingly conceptualised as a proxy for physical health, two biomechanical models have been proposed in which higher HRV also reflects the neural capacity to regulate the expression of emotion. In brief, the neurovisceral integration model (Thayer, Hansen, Saus-Rose, & Johnsen, 2009; Thayer & Lane, 2000) suggests that greater relative parasympathetic activation corresponds to a higher degree of prefrontal cortex integration. This integration then allows for greater attentional and affective information processing and the top down regulation of behaviour. Thus, HRV may index the neural capacity to direct resources towards affective information processing and the regulation of behaviour and, therefore, the ability to deliberately regulate the expression of emotion (Thayer & Brosschot, 2005; Thayer et al., 2009; Thayer & Lane, 2000; Thayer & Lane, 2009). In a similar vein, the polyvagal theory (Porges, 2001, 2007) suggests that the myelinated vagus evolved as part of a social nervous system that is responsible for orientation to the environment and social communication. Given that the vagus is responsible for both cardiac output *and* the cranial nerves necessary for facial expressivity, higher HRV should reflect greater social engagement and the ability to manipulate facial musculature to effectively regulate emotional expressive behaviour (Porges, 2001, 2007).

Therefore, in examining potential links between expressive regulatory skills and physical health parameters, the current chapter presents an empirical study testing whether the objectively assessed ability to flexibly up- and down-regulate expressions of joy, sadness, and anger predicts health outcomes, and whether distinct emotional expressions are differentially associated with symptom interference, and resting HRV.

6.2 Citation

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6.3 Abstract

Objectives: The outward expression of emotion has been frequently associated with better health outcomes, whereas suppressing emotion is thought to contribute to worse physical health. However, work has typically focused on trait expressive tendencies and the possibility that individual differences in the ability to express specific emotions may also be associated with health has not been widely tested.

Design: A cross sectional study of community dwelling adults. **Methods**: One hundred and twenty eight participants aged 18-88 years completed questionnaires assessing demographics and health status, before attending a testing session in which resting heart rate variability (HRV) was assessed. Participants then completed a performance-based test of expressive regulatory skill in which they were instructed to enhance and suppress their emotional expressions while they watched film clips validated to elicit amusement, sadness, and anger. Participants rated subjective emotional experience before and after each clip, and their degree of expressivity was scored using FACS-based Noldus Facereader. **Results**: Missing data resulted in a final sample size of 117. Linear regressions controlling for age, sex, diagnoses, and trait emotion revealed that greater ability to enhance sad expressions was associated with higher HRV while the ability to enhance expressions of joy was associated with lower symptom interference. In parallel models, the ability to flexibly regulate (both enhance *and* suppress) expressions of joy and sadness also were also associated with lower symptom interference. **Conclusions**: Findings suggest that the *ability* regulate expressions of both sadness and joy is associated with health indices even when controlling for trait affect and potential confounds. The present findings offer early evidence that individual differences in the ability to regulate the outward expression of emotion may be relevant to health and suggest that expressive regulatory skills offer a novel avenue for research and intervention.

6.4 Introduction

The outward expression of positive emotion has been repeatedly associated with better health outcomes, whereas the tendency to inhibit or suppress expressivity is widely thought to be detrimental for physical health (Appleton et al., 2014; DeSteno et al., 2013; Greenberg, Wortman, & Stone, 1996; John & Gross, 2004; Mauss & Gross, 2004). For example, greater positive expressivity prospectively predicts lower 10-year incident coronary heart disease (CHD) (Davidson et al., 2010), and more frequent laughter predicts lower CHD prevalence (Hayashi et al., 2016). In addition to positive emotion, the expression of anger has been associated with reduced cardiovascular disease risk (Eng, Fitzmaurice, Kubzansky, Rimm, & Kawachi, 2003), whereas characteristically suppressing or inhibiting emotions is thought to be a risk factor for poorer health outcomes (Burns et al., 2007; Haynes et al., 1980; Kerns et al., 1994; Suls & Bunde, 2005).

Work examining links between expressive regulation and health has been largely informed by the process model of emotion regulation (Gross, 1998b). This model categorises emotion regulatory strategies according to the stage in the emotion generative process at which regulation occurs. Within this model, expressive regulation (termed response modulation) only occurs once an emotion is already active. By contrast, antecedent-focused strategies, such as cognitive reappraisal or situation selection, occur earlier in the emotion generative process (Gross, 1998b).

Experimental work using between-group designs has typically found that when compared with antecedent-focused strategies (such as cognitive reappraisal), expressive suppression has a detrimental impact on physiological, cognitive, and social outcomes (Bonanno et al., 2004; Gross & John, 2003; Korb et al., 2012; Kunzmann et al., 2005). However, although findings are frequently interpreted as evidence that suppressing emotions is detrimental to physical health (Consedine, Magai, & Bonanno, 2002), work in this tradition is limited to the investigation of the immediate effects of manipulated expressive suppression. Such findings cannot be extrapolated to long term physical health.

In addressing this limitation, cross-sectional and prospective studies have examined whether self-reported trait expressive regulation is also associated with health outcomes. Again, these studies suggest that, when compared with other strategies, the tendency to suppress expressivity corresponds with worse physical health, including greater risk of incident hypertension (Everson et al., 1998), the development of coronary heart disease (CHD) (Haynes et al., 1980), and all-cause, cardiac, and cancer mortality (Chapman et al., 2013; Graves et al., 1994; Harburg et al., 2003; Haynes et al., 1980). However, despite providing evidence that emotion regulation is an important predictor of health, work to date is limited by a focus on self-reported trait regulation, and studies are yet to examine whether individual differences in the ability to enhance or suppress emotional expressivity might also be associated with physical health.

Although there is a lack of empirical work, theoretical accounts suggest that regulatory skills should be an important predictor of outcomes. Because emotional expressions serve a social signalling function (rather than necessarily mapping onto internal feeling states), expressions are often deliberately regulated to effectively manage social interactions (Fridlund, 1997, 2014; Hareli & Hess, 2010; Manstead, 1991; Parkinson, 1996; Van Doorn et al., 2012). Factors such as individual goals, aspects of the environment, and cultural display rules govern the type and amount of expressivity appropriate to any given situation (Ekman et al., 1972; Fridlund, 1997, 2014; Hareli & Hess, 2012; Malatesta & Haviland, 1982; Matsumoto, 1990; Mitchell, 1999; Saarni, 1979). As such, rather than a stable tendency to express or inhibit emotion in a particular manner (as indexed by trait measures), the ability to flexibly express and suppress emotion in a way that it sensitive to situational demands may be a more appropriate means of conceptualising healthy emotion regulation (Coifman & Bonanno, 2009, 2010; Coifman, Bonanno, Ray, & Gross, 2007; Gupta & Bonanno, 2011).

In addition to theoretical support for the examination of skills, adopting a skills-based approach has methodological advantages over trait assessments. First, self-reported trait assessments are vulnerable to reporting biases, and correlating self-reported traits with self-reported outcomes is likely to artificially inflate associations due to method-related covariation (Podsakoff et al., 2012). Second, trait emotion regulation, particularly expressive suppression, has been reliably associated with trait emotionality, primarily greater negative affect (NA) (Brans et al., 2013; Brotheridge & Grandey, 2002; Consedine, Magai, Cohen, et al., 2002), anger (Consedine et al., 2005; Martin & Watson, 1997; M. A. Russell et al., 2016), and depression (Franchow & Suchy, 2015; Haga et al., 2009). In turn negative emotionality is an established predictor of poorer health (for reviews see Consedine & Moskowitz, 2007; Mayne, 1999). If people reporting high trait suppression also have greater NA, then negative emotionality may conflate the links between expressive suppression and poorer health (e.g. Bruehl, Chung, & Burns, 2003; Bruehl, Chung, Burns, et al., 2003; Nicholson et al., 2003). Indeed, links between suppression and poorer outcomes are often diminished once NA or depression are controlled for (e.g. Appleton, Buka, Loucks, Gilman, et al., 2013; Bruehl, Chung, & Burns, 2003; Bruehl, Chung, Burns, et al., 2003; Nicholson et al., 2003). By contrast, expressive regulatory skills can be assessed using objective, performance based tests and offer a measure of the ability to flexibly adjust expressive behaviour that is less vulnerable to reporting biases and third variable confounds.

Finally, in addition to theoretical and methodological advantages, early empirical work indicates that expressive skills predict better psychological outcomes (Bonanno et al., 2004; Coifman & Bonanno, 2009; Gupta & Bonanno, 2011). For example, an early study among college students found that the ability to both enhance and suppress positive and negative expressions prospectively predicted better psychological adjustment over a 2-year period (Bonanno et al., 2004). Regulatory skills have also been associated with better peer-reports of psychological adjustment (Westphal et al., 2010) greater verbal fluency (Gyurak et al., 2012; Gyurak et al., 2009), and resilience to trauma (Levy-Gigi et al., 2016; Orcutt et al., 2014), whereas deficits in expressive flexibility predict poorer adaptation and slower recovery from bereavement (Gupta & Bonanno, 2011).

More directly relevant to physical health, expressive skills have been associated with physiological parameters, particularly heart rate variability (HRV) (e.g. Demaree, Pu, et al., 2006; Kettunen, Ravaja, Näätänen, & Keltikangas-Järvinen, 2000; Tuck, Grant, Sollers III, Booth, & Consedine, 2016). HRV is a measure of the beat-to-beat variation in heart rate, and reflects the output of the central autonomic network (Thayer, Åhs, Fredrikson, Sollers III, & Wager, 2012). Although not a clinical health outcome in its own right, HRV is widely considered to be a proxy for physical health status (Kok et al., 2013), and low HRV has been identified as a risk factor for poorer health outcomes, including immune dysfunction, inflammation (Lampert et al., 2008), the metabolic syndrome (Liao et al., 1998; Stein et al., 2007), ischaemic heart disease heart failure (Dekker et al., 2000), and diabetes (for reviews see Kemp & Quintana, 2013; Thayer, Yamamoto, & Brosschot, 2010).

Consistent with self-reported outcomes, studies examining links between expressive regulatory skill and HRV have found that greater expressive skill is associated with higher HRV, thought to reflect better physical health (Demaree, Pu, et al., 2006; Demaree, Robinson, et al., 2004; D. C. Jackson et al., 2000). However, with the exception of one recent report (Tuck, Grant, Sollers III, et al., 2016), studies have operationalised expressive skills in terms of broad positive or negative valence, and have not looked at the ability to flexibly regulate specific emotions. Discrete emotions have precise signals that serve specific functions within the social environment (e.g. Fischer et al., 2012; Fischer & Roseman, 2007; Keltner, 1995). Consequently, some emotions may be more closely related to physical health than others (Tuck, Grant, Jackson, Brooks, & Consedine, 2016; Tuck, Grant, Sollers III, et al., 2016), and valence-based assessments of positive/negative expressivity may obscure emotion-specific links.

Given this background, the broadest aim of the present report was to test for links between the ability to enhance and suppress the expression of three common emotions – sadness, joy, and anger – and both self-reported physical symptoms, as well as a more objective physiological parameter; HRV. The absence of prior studies in this area precluded predictions other than a general expectation that greater skill would be associated with better outcomes (Kubzansky et al., 2011; Potijk et al., 2016; Tuck, Grant, Jackson, et al., 2016; Tuck, Grant, Sollers III, et al., 2016) as indexed by lower symptom interference and higher HRV.

6.5 Methods

6.5.1 Study Design

This report represents a secondary analysis of an experimental study examining lifespan differences in emotion regulation. As such, the experimental condition variable (variation in instructions preceding the expressive skill task) is included as a covariate to control for any potential experimental group differences in expressive skill. In addition, skill-by-condition interactions were examined to confirm that the experimental condition did not systematically impact the links between expressive skills and health outcomes (see Procedures for details).

6.5.2 Participants

One hundred and forty one English language-fluent participants aged 18-88 years (mean age = 41.83, SD = 16.61), were recruited in Auckland, New Zealand via university and hospital mailing lists, poster, and flyer advertisements for a study of 'Emotions across the Lifespan.' Of the 141 completing baseline measures, 128 attended the laboratory session. Of these, 6 had video data that was not of sufficient quality for analysis, and 1 was missing experiential state emotion reports. Additionally, due to equipment failures, 4 had missing heart rate data. As such, analyses were run on a final sample of 117 participants (men = 40%), see Table 1 for descriptive statistics.

6.5.3 Procedure

Participants completed online measures of demographics, trait emotion, and health approximately two weeks before attending a testing session in a psychophysiology laboratory. This temporal distance was created to reduce the likelihood that state or momentary changes in mood, health, or other potential third variable confounds, would concurrently influence both predictor and outcome variables, and artificially inflate links (see Podsakoff et al., 2012). On arrival, a three-lead electrocardiogram (ECG) was fitted to measure HRV. Participants then completed an online measure of emotional intelligence (EI), before sitting quietly for 5 minutes while resting HR was recorded. HR and digital video of participants were continuously recorded for the remainder of the testing session. EI data are not reported here.

Table 6.1 Descriptive Statistics for study variables

		Mean	SD	Min	Max	Skew
Confounds	HRV [a]	3.50	0.57	1.82	5.24	-0.14
	Symptom Interference [a]	1.55	1.09	0.00	3.56	-0.11
	Condition	0.48	0.50	0.00	1.00	0.06
	Diagnoses	0.26	0.44	0.00	1.00	1.12
	Age	41.83	16.61	18.00	88.00	0.36
	Sex [b]	1.60	0.49	1.00	2.00	-0.42
Trait Emotion	Trait Joy	3.74	0.67	1.67	5.00	-0.38
	Trait Sadness	2.27	0.79	1.00	4.00	0.24
	Trait Anger	2.01	0.82	1.00	5.00	0.92
Expression and Inhibition Scores [c]	Joy Express	0.48	0.23	0.01	0.86	-0.45
	Joy Natural	0.34	0.23	0.00	0.88	0.26
	Joy Inhibit	0.14	0.16	0.00	0.70	1.47
	Anger Express	0.42	0.25	0.01	0.91	0.12
	Anger Natural	0.39	0.25	0.00	0.96	0.27
	Anger Inhibit	0.37	0.26	0.01	0.86	0.21
	Sad Express	0.08	0.12	0.00	0.60	2.29
	Sad Natural	0.07	0.11	0.00	0.62	2.54
	Sad Inhibit	0.06	0.12	0.00	0.63	3.21
Relative Skill Scores	Joy Enhance	0.14	0.20	-0.68	0.64	-0.50
	Joy Suppress	0.20	0.21	-0.35	0.82	0.46
	Anger Enhance	0.03	0.17	-0.35	0.70	0.92
	Anger Suppress	0.03	0.17	-0.65	0.53	-0.39
	Sad Enhance	0.01	0.07	-0.32	0.29	0.10
	Sad Suppress	0.01	0.07	-0.32	0.34	0.30
Flexibility Scores	Joy Flexibility	0.09	0.30	-1.36	0.70	-1.33
	Sad Flexibility	-0.04	0.12	-0.63	0.33	-2.35
	Anger Flexibility	-0.14	0.26	-1.30	0.39	-0.89

Note: [a] scores are log transformed, [b] 1= Men, 2 = Women, [c] Scores are square root transformed

To assess skill in flexibly regulating facial expressions of emotion, participants watched three film clips, each approximately four minutes long, and validated to elicit amusement, sadness, and anger (Gross & Levenson, 1995; Schaefer, Nils, Sanchez, & Philippot, 2010). Clips from 'In the Name of the Father' and 'Philadelphia' were selected to elicit anger and sadness respectively (see Schaefer et al., 2010 for details) and a segment from a Robin Williams comedy show was used to elicit amusement (see Gross & Levenson, 1995 for details). After watching each clip naturally for approximately one minute, on-screen instructions asked participants to enhance the expression of any felt emotion until instructed otherwise. After one minute of up-regulating expressivity, participants were instructed to watch the film naturally for one minute and, in the final segment, participants were instructed to suppress any visible expression of emotion. Instructions were delivered in this order based on the premise that the experience of the target emotion would increase (rather than decrease) across the course of the film clip, meaning that expressive capacity was assessed at the times when it would be more challenging to enhance expressions (at the beginning when less emotion was felt) and suppress expressions (at the end when more was felt). The order of the two negative emotional films (i.e. sad and angry) was counterbalanced as the first and third clips, while the second was always the amusing clip. This order was used to systematically shift emotional experience from negative to positive and back, providing an opportunity for emotions to recover. Following each film clip participants completed a measure of felt emotion and, after watching all three films, participants completed a brief task in which they were photographed while deliberately posing facial expressions of 10 target emotions. Participants were then thanked for their time and given a $40 petrol voucher. Photo data are not considered in this report.

As outlined above, to address a separate research question participants were randomised to either a 'warned' or an 'un-warned' condition. Before the film task, those in the 'warned' condition were given brief information regarding the emotion that each film was intended to elicit, and were told that they would be instructed to enhance and suppress their facial expressions while watching. Those in the un-warned condition were told that instructions would appear periodically throughout the film clips, and that they should do their best to follow them. They were not given information about the emotions that the films would elicit, or that they would be instructed to enhance and suppress expressions. The condition variable was co-varied in analyses and there were no significant effects or associations between the condition variable and either predictor or outcome variables in this report. As a further precaution, interaction terms were examined to confirm that skill-by-condition interactions did not systematically predict outcomes.

6.5.4 Measures

Demographics: Age and sex were self-reported; mean (age) = 41.83, SD = 16.61, male = 39.8% (see Table 1).

Diagnosis Counts: Participants indicated (yes/no) whether or not they had a current heart or bowel condition, compromised immune function, cancer, other serious health problem, or psychological diagnosis. The presence of a confirmed diagnosis was scored on a present (25.8%) / absent (74.2%) basis (Table 1).

Trait Emotion: Participants completed the 30 item 'Trait' DES III (Izard, Dougherty, Bloxom, & Kotsch, 1974), which measures the degree to which 10 fundamental emotions are characteristic of participants' day to day living. Three items assess each of 10 discrete emotions (guilt, joy, sadness, embarrassment, fear, contempt, anger, surprise, disgust, and interest) and participants indicate the degree to which each emotion is felt in daily life on scales from 1 (not at all) to 5 (extremely). The DES has good reliability (Izard et al., 1974) and discriminant validity (Boyle, 1984). In the present report scores for trait anger (α = .82), sadness (α = .83), and joy (α = .85) were computed by taking the average score for each subscale (Table 1).

State Emotion: Before and after each film clip, participants completed the 10-item Brief Differential Emotions Scale (Brief DES) (Malatesta & Izard, 1984), an adaptation of the 30 item 'State' DES III (Izard, 1972; Youngstrom & Green, 2003). The 10-item Brief DES (Malatesta & Izard, 1984) assesses the degree to which participants are currently feeling each of 10 emotions: guilt, joy, sadness, embarrassment, fear, contempt, anger, surprise, disgust, and interest, on a scale ranging from 1 (not at all) to 5 (extremely). The Brief DES is preferred over the full-scale DES when repeated administrations are used over short intervals of time (Malatesta & Izard, 1984) as was the case in the present study (Table 1).

Symptom Interference: The 42-item Physical Symptoms Inventory (PSI) (Wahler, 1968) was used to test the degree to which participants were bothered by physical symptoms such as "headaches" and "heart trouble" over the prior three months. For symptoms that participants reported experiencing, they indicated the degree to which each symptom interfered with daily living on a scale from 1 (not at all) to 5 (very much). The PSI has strong reliability and adequate validity (Wahler, 1968), with prior work reporting internal consistency estimates ranging from .82 - .94 (Consedine & Butler, 2014; Consedine et al., 2006; Tuck, Grant, Jackson, et al., 2016) and test–retest reliability ranges from .45 to .94 (Consedine et al., 2006). In the present report Cronbach's α = .81, and mean (SD) = 1.55 (1.09). To correct for positive skew, scores were log transformed. However, as a score of zero cannot be log transformed, those reporting no symptoms (N=23) retained a score of zero rather than being re-coded by SPSS as missing (Table 1).

HRV: A three lead electrocardiogram (ECG) was used to record HR. Electrodes were attached to the right sternum and on the left and right abdomen. Successive R–R intervals were recorded using Mindware software during a 5-minute spontaneous breathing and resting 'baseline.' The sampling frequency was set at 1000 Hz, providing a temporal resolution of 1ms for each R–R interval. R-R data were de-trended (Smoothness priors, k = 500) (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014), and interpolated at 4 Hz, and artefact corrected (low to medium strength) using Kubois HRV 2.0 (Tarvainen et al., 2014). An autoregressive spectral analytic approach was employed for the frequency domain measurements using model order 16 (Boardman, Schlindwein, & Rocha, 2002). In the present study we report HRV results using the root mean square of successive differences (RMSSD), a time-domain measure of HRV that is valid (Thayer & Sternberg, 2010), stable (Li et al., 2009), and primarily reflects trait influences (Bertsch, Hagemann, Naumann, Schächinger, & Schulz, 2012). Data were log transformed to correct for positive skew. The present report did not control for respiration as this is not necessary when breathing spontaneously (G. F. Lewis, Furman, McCool, & Porges, 2012; Thayer, Loerbroks, & Sternberg, 2011) (see Table 1).

Expressive Regulatory Skill: Digital video recordings of participants during the enhance and suppress phases of the sad, amusing, and anger inducing film clips were scored using Noldus FaceReader™ version 5.0 (Loijens et al., 2014). This automated scoring system is derived from the standard Facial Action Coding System (FACS) and scores expressivity by detecting facial muscle contractions such as raising cheeks and lip tightening. FaceReader has good construct validity (A. S. Cohen, Morrison, &

Callaway, 2013) and accuracy when compared with manually coded FACS scores (Lewinski, 2015). FaceReader assigns a value between 0 and 1 to each of six discrete emotions; joy, sadness, surprise, anger, fear, and disgust, recording scores every 40 milliseconds.

To accommodate slight differences in the length of digital recordings, the raw scores for up- and down-regulating expressivity were derived by first averaging the degree of facial expressivity recorded across the 'enhance' or 'suppress' phase of the relevant film clip. These scores, as well as expressivity scored during the 'natural' viewing phase were positively skewed so were square root transformed to improve distributions. As in prior work (e.g. Westphal et al., 2010), scores indexing the relative ability to enhance expressions of joy, sadness, and anger were calculated by subtracting expressivity scores from the natural watch condition, from those during the enhance condition. The ability to suppress expressivity was similarly calculated by subtracting expressivity during the suppress condition from expressivity during the natural watch condition.

Following this, expressive flexibility scores were derived as follows; first, scores indexing skill in up-regulating and down-regulating expressivity for each emotion were summed, second, polarity scores were calculated as the absolute difference between the up-regulation and down-regulation scores. Third, a balanced expressive flexibility score was calculated by subtracting polarity scores from the sum flexibility scores. This creates a balanced flexibility score that captures the degree to which a person is equally able to engage in both types of expressive regulation. Because extreme scores in one direction (but not the other) results in a lower balance score (Westphal et al., 2010), high balanced flexibility scores are not unduly influenced by high skill in a single strategy (e.g. down-regulating) but low skill in the other (e.g. up-regulating), for descriptive statistics see Table 1.

6.5.5 Analytic Strategy

Paired samples *t*-tests were used to test the degree to which state emotion was successfully manipulated by viewing the film stimuli. Next, to confirm that participants followed instructions to regulate expressivity, independent samples *t*-tests were used test whether expressivity scores differed in the expected directions across the 'enhance', 'natural viewing', and 'suppress' conditions. Univariate relationships between study variables were then assessed with Pearson's and Spearman's (where appropriate) correlations. Following this, two linear regressions were used to test whether expressive skill scores were associated with symptom interference and HRV, while controlling for potential confounds. In each model age, sex, having a current diagnosis, and experimental condition were entered in the first step, along with trait joy, sadness, and anger. Skills scores for the ability to enhance and suppress expressions of joy, sadness and anger were then entered in the second step. Following this, two additional regression models were used to test whether flexibility scores would also be associated with health indices. Finally, to rule out any potential effect of warning participants regarding upcoming tasks, an additional step was added to each model to include skill*warning interaction terms.

6.6 Results

6.6.1 Manipulation checks: State emotion

Paired samples *t*-tests based on self-reported emotion before and after each film clip demonstrated that target emotions increased as a result of the film inductions for joy t (126) = 6.93, p <.001, sadness, t (126) = 10.83, p <.001, and anger, t (125) = 12.01,

p <.001. Additionally t-tests with Bonferroni corrections (α = .005) demonstrated that following the amusing film, state joy was significantly higher than other all emotions (all p's < .001). Following the anger induction, anger was significantly higher than most emotions (p's < .001) with the exception of sadness and interest which were not significantly different from anger, and disgust which was greater than anger (t = 15.01, p < .001). Following the sad film, sadness was significantly higher than other emotions (p's < .001), again with the exception of interest which was not significantly different from sadness (p > .005).

Manipulation Checks: Expressive skill task

Expressivity was significantly greater in the 'enhance' than the 'suppress' condition for joy t (125) = 15.68, p <.01, sadness t (125) = 2.71, p <.01, and anger t (121) = 2.84, p <.01. Additionally, expressivity for the enhance condition was greater than the 'natural watch' condition for joy t (124) = 7.78, p < .01, however this difference was marginal for both sadness, t (125) = 1.71, p < .10, and anger, t (122) = 1.83, p < .10. Finally, expressivity in the 'natural' condition was significantly greater than in the 'suppress' condition for joy t (124) = 10.75, p < .01. However, although scores were in the expected direction, expressivity during the 'natural' condition was not significantly greater than expressivity during the 'suppress' condition for anger t (124) = 1.65. p = .10, or sadness, t (126) = 1.47. p = .15.

6.6.2 Bivariate correlations

Consistent with work by other groups (Westphal et al., 2010), the ability to enhance expressivity was inversely correlated with the ability to suppress expressivity for joy, (r = -.31, p < .01), sadness, (r = -.22, p < .05), and anger, (r = -.19, p < .05) (Table 2).

Bivariate correlations revealed that the ability to enhance the expression of joy was associated with lower symptom interference, skill in suppressing joy was associated with fewer diagnoses, and skill in flexibly regulating joy was also associated with lower symptom interference. Additionally, greater skill in both enhancing, and suppressing the expression of sadness were both marginally associated with higher HRV, whereas skill in flexibly regulating anger was marginally associated with lower HRV (Table 2).

6.6.3 Multivariate regressions predicting health indices

Symptom Interference

Entry of covariates age, sex, diagnoses, experimental condition, and state emotion in Step 1 produced a significant model F (7,109) = 4.03, $p < .01$, explaining 21% variance in symptom interference. Having a diagnosis ($\beta = .22$, $p < .05$), and trait sadness ($\beta = .35$, $p < .01$), were associated with greater symptom interference. The addition of expressive skill variables in Step 2 also produced a significant model F (13, 103) = 2.57, $p < .01$, explaining 4% additional variance, although the change in F was not significant, $F\Delta$ (6, 103) = 0.91, $p > .10$. Having a diagnosis ($\beta = .21$, $p < .05$), and trait sadness ($\beta = .33$, $p < .01$), continued to be associated with greater symptom interference, whereas skill in up-regulating expressions of joy was associated with lower symptom interference ($\beta = -.21$, $p < .05$) (see Table 3).

An alternative model was then run with flexibility metrics entered in the place of the enhancing and suppressing expressivity scores. The addition of flexibility metrics in Step 2 produced a significant model F (10, 106) = 3.86, $p < .01$, explaining 6% additional variance, $F\Delta$ (3, 109) = 2.97, $p < .05$. Having a diagnosis ($\beta = .20$, $p < .05$) and trait sadness ($\beta = .33$, $p < .01$) continued to show links with greater symptom interference, whereas skill in flexibly up- and down-regulating expressions of joy ($\beta =$

Table 6.2 Bivariate correlations between study variables

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	HRV																	
2	Symptom Interference	.02																
3	Condition [a]	.05	-.05															
4	Diagnoses [a]	-.07	.22*	.00														
5	Age	-.33**	-.08	-.07	.31**													
6	Sex [a]	.00	.20*	-.01	-.07	.02												
7	Trait Joy	.06	-.01	.08	-.01	-.01	-.03											
8	Trait Sad	.12	.39**	-.12	.07	-.17ŧ	.23**	-.42**										
9	Trait Anger	.08	.22*	.00	.00	-.05	.12	-.32**	.62**									
10	Joy Enhance	.08	-.19*	.14	-.10	-.09	-.03	.05	-.10	.00								
11	Joy Suppress	-.07	-.04	.06	-.19*	-.07	.02	.22*	-.15	-.10	-.31**							
12	Sad Enhance	.17ŧ	.05	-.05	.10	-.06	-.01	.12	.02	-.10	.11	-.02						
13	Sad Suppress	.17ŧ	-.02	.07	-.01	-.09	.03	.08	.03	.03	-.06	.01	-.22*					
14	Anger Enhance	-.14	.05	.06	-.05	.06	-.09	-.07	.09	.19*	.16ŧ	-.11	.10	-.02				
15	Anger Suppress	-.10	-.02	.01	.06	.07	.04	-.13	.06	.14	.05	-.12	-.08	-.04	-.19*			
16	Joy Flexibility	.11	-.18*	.12	-.14	-.10	.03	.15ŧ	-.14	-.05	.67**	.12	.08	-.07	.02	-.02		
17	Sad Flexibility	.06	-.13	.05	.14	.13	-.08	.16ŧ	-.11	-.12	.04	.05	.51**	.28**	.08	-.08	-.05	
18	Anger Flexibility	-.17ŧ	-.01	.03	.03	.08	-.08	-.13	.18*	.22*	.07	-.08	-.08	.01	.42**	.53**	.00	-.14

** *p* <.01, * *p<.05*, ŧ *p* <.10

[a] Spearman's Rho correlation coefficients are reported for dichotomous variables

[b] 1 = Men, 2 = Women

19, $p < .05$), and expressions of sadness ($\beta = -.18$, $p < .05$), was associated with lower symptom interference (Table 4).

Heart rate variability

Entry of covariates and state emotion in Step 1 did not produce a significant model F (7, 109) = 1.76, $p = .10$, explaining 10% variance in HRV, with older age being associated with lower HRV ($\beta = -.31$, $p < .01$). The inclusion of skill variables in Step 2 however did produce a significant model, F (13, 103) = 1.84, $p < .05$, explaining 9% additional variance, although the change in F was not significant, $F\Delta$ (6, 103) = 1.83, p = .10. Skill in up-regulating sad expressions ($\beta = .20$, $p < .05$), was associated with higher HRV, and skill in down regulating sad expressions was marginally associated with higher HRV ($\beta = .17$, $p < .10$) (see Table 3).

An alternative model was then run with flexibility scores entered in the place of individual enhance/suppress metrics. The addition of flexibility scores in Step 2 produced a marginal model F (10, 106) = 1.89, $p = .06$, explaining 5% additional variance, although the change in F was not significant $F\Delta$ (3, 106) = 2.05, $p > .10$. Older age continued to show links with lower HRV ($\beta = -.28$, $p < .01$), and skill in flexibly regulating anger was marginally associated with lower HRV ($\beta = -.17$, $p = .07$) (Table 4).

Finally, to confirm that being warned regarding the up-coming expressive skill tasks did not systematically influence findings, skill*warning interaction terms were entered in a third step for all four models. The addition of interaction terms did not produce any significant changes in F (all p values > .10). Although most interaction terms were non-significant predictors of outcomes, (p values > .10), the interaction between condition and enhancing anger expressions was marginally associated with both HRV ($\beta = -.24$, $p < .10$), and symptom reports ($\beta = -.23$, $p < .10$). This pattern suggests that although the warning condition may be relevant for anger, the observed

Table 6.3 Results showing the final step in two linear regressions, where potential covariates and state emotion were entered in the first step, followed by expressive regulatory skills in the second step

	Symptom Interference				HRV			
	B	SE	Beta	sr^2	B	SE	Beta	sr^2
Condition	-0.04	0.19	-0.02	0.00	-0.03	0.10	-0.03	0.00
Diagnoses	0.52	0.24	0.21*	0.03	-0.02	0.13	-0.01	0.00
Age	-0.01	0.01	-0.17 ᵼ	0.02	-0.01	0.00	-0.28**	0.06
Sex [a]	0.35	0.20	0.16 ᵼ	0.02	-0.03	0.11	-0.03	0.00
Trait Joy	0.26	0.16	0.17	0.02	0.01	0.08	0.01	0.00
Trait Sadness	0.46	0.17	0.33**	0.05	0.02	0.09	0.02	0.00
Trait Anger	0.01	0.16	0.01	0.00	0.03	0.08	0.04	0.00
Joy Enhance Skill	-0.22	0.10	-0.20*	0.03	0.01	0.06	0.02	0.00
Joy Suppress Skill	-0.08	0.11	-0.08	0.00	-0.06	0.06	-0.10	0.01
Sad Enhance Skill	-0.05	0.10	-0.04	0.00	0.11	0.05	0.20*	0.04
Sad Suppress Skill	-0.06	0.09	-0.06	0.00	0.09	0.05	0.17 ᵼ	0.03
Anger Enhance Skill	-0.03	0.11	-0.02	0.00	-0.08	0.06	-0.13	0.02
Anger Suppress Skill	-0.05	0.10	-0.05	0.00	-0.07	0.05	-0.13	0.02

Note: ** $p < .01$, * $p < .05$, ᵼ $p < .10$ sr^2 = squared part correlations

[a] 1 = Men, 2 = Women

Table 6.4 Results showing the final step in two linear regressions, where potential covariates and state emotion were entered in the first step, followed by expressive flexibility metrics in the second step

	Symptom Interference				HRV			
	B	SE	Beta	sr^2	B	SE	Beta	sr^2
Condition	-0.03	0.18	-0.01	0.00	-0.03	0.10	-0.03	0.00
Diagnoses	0.51	0.22	0.20*	0.04	0.06	0.12	0.04	0.00
Age	-0.01	0.01	-0.12	0.01	-0.01	0.00	-0.29**	0.07
Sex[a]	0.38	0.20	0.17ƚ	0.03	-0.07	0.11	-0.07	0.00
Trait Joy	0.29	0.15	0.18ƚ	0.03	0.01	0.08	0.02	0.00
Trait Sadness	0.46	0.17	0.33**	0.05	0.08	0.09	0.11	0.01
Trait Anger	-0.03	0.15	-0.02	0.00	0.01	0.08	0.01	0.00
Joy Flexibility Skill	-0.21	0.09	-0.19*	0.03	0.07	0.05	0.13	0.01
Sad Flexibility Skill	-0.18	0.09	-0.18*	0.03	0.05	0.05	0.09	0.01
Anger Flexibility Skill	-0.08	0.09	-0.08	0.01	-0.09	0.05	-0.17ƚ	0.03

Note: ** $p < .01$, *$p < .05$, ƚ $p < .10$ sr^2 = squared part correlations

[a] 1 = Men, 2 = Women

links between regulating expressions of sadness and joy with outcomes were not unduly or systematically influenced by the experimental condition.

6.7 Discussion

The dispositional tendency to outwardly express emotion has been repeatedly associated with better health outcomes, whereas the suppression of emotion is thought to predict worse physical health. To this, the present report adds early evidence that individual differences in the *ability* to express and suppress both positive and negative emotions are also associated with indices of physical health. Consistent with expectations, greater skill in enhancing joy was associated with lower symptom interference, whereas skill in enhancing sadness was associated with higher HRV. In addition to this, the ability to flexibly up- and down-regulate both joy and sadness were also associated with lower reported symptom interference[1]. Below these findings are evaluated in the context of prior work linking expressive flexibility to outcomes, preliminary interpretations are offered, limitations are identified, and directions for future research are considered.

[1] *In addition to the published results presented in this chapter, additional models were run to test for potential moderating effects of age, gender, and ethnicity. In each model, potential confounds were entered in the first step, followed by the hypothesised moderator, then skill, then the moderator*skill interaction term. Analyses indicated that none of the observed effects were moderated by age, sex, or ethnicity.*

6.7.1 Expression, suppression, and expressive flexibility in physical health

The primary contribution of this report lies in extending links with psychological wellbeing (e.g. Bonanno et al., 2004), to show that the ability to both enhance and suppress the expression of emotion has links with indices of physical health. The finding that skill in expressing joy was associated with lower symptom interference is consistent with studies documenting links between positive expressivity and better health (e.g. Davidson et al., 2010; Hayashi et al., 2016) and demonstrates that, in addition to trait positive emotion, the *ability* to express positive emotion is also associated with better outcomes.

Furthermore, findings that skill in *flexibly* regulating both joy and sadness were also associated with lower symptom interference, and that the ability to enhance sad expressions was associated with higher HRV, indicate that links to health are not specific to enhancing positive emotion. Rather, the ability to enhance and suppress, both positive and negative expressions, appears to have important implications for physical health. Such findings are consistent with theoretical work (Bonanno & Burton, 2013; Consedine & Mauss, 2014; Kashdan & Rottenberg, 2010), and with studies in mental health (Beauregard, Paquette, & Levesque, 2006; Bonanno et al., 2004), which indicate that the *ability* to flexibly regulate expressions in accordance with situational demands is most adaptive (Gupta & Bonanno, 2011). To this, the present findings represent the first evidence that the ability to flexibly regulate both sadness and joy are also associated with physical health parameters.

6.7.2 Disentangling trait emotion from expressive regulatory skills

A second contribution of this report lies in demonstrating that links between expressive regulatory ability and health persist even when controlling for trait emotion. This observation is conceptually and methodologically important because although trait emotion regulation has been repeatedly associated with health, it is frequently unclear whether links between emotion regulation and outcomes are specific to the *expression* of emotion, or whether differences in underlying trait affect are responsible (Burns, Quartana, & Bruehl, 2008; Consedine, Magai, & Bonanno, 2002). In demonstrating that the *ability* to regulate emotional expressions corresponds with outcomes even when controlling for trait affect, these data suggest that links between expressive regulation and outcomes are specific to expressive regulatory *skills*, and not attributable to personality-level differences in trait emotion.

6.7.3 Beyond valence: specific positive and negative emotions may matter

Third, evidence that the ability to enhance and suppress expressivity are inversely correlated, and that expressive regulatory skills for distinct emotions are not associated with each other suggests that skills in regulating specific emotions do not represent a single overarching ability (at least as operationalised in this manner). Rather, the ability to flexibly regulate distinct emotions appears to reflect multiple skills, of which some are more closely related to the health metrics employed here than others. Prior work has assessed expressive skills in terms of broad, positive or negative valence. However, the finding that skill in flexibly regulating anger was marginally associated *lower*, while skill expressing sadness was associated with *higher* HRV, indicates that link between skills and objective physical parameters are likely complex, and a valence-based approach may obscure associations. As such, a discrete emotions approach to the assessment of expressive regulatory skills is warranted.

6.7.4 Possible mechanisms

Although the present data do not allow for the examination of mechanisms, it is possible that social factors, a broad capacity to regulate behaviour in general, and/or underlying autonomic pathways are at least partially responsible for the links between expressive regulatory skills and physical health. Prima facie, the ability to regulate the expression of emotion in a manner that is consistent with the demands of a given situation (such as display rules) is likely to correspond with better social functioning (Bonanno & Burton, 2013; Hareli & Hess, 2012), and consequently better physical health, via stress buffering and other social parameters (S. Cohen & Wills, 1985; Kok & Fredrickson, 2010). Equally, it is possible that the regulatory skills assessed here reflect only one aspect of a broader capacity to regulate behaviour in a manner that facilitates goal attainment, which in turn has been associated with positive health outcomes (see de Ridder, Lensvelt-Mulders, Finkenauer, Stok, & Baumeister, 2012 for a review; Kubzansky et al., 2011; Potijk et al., 2016). Finally, and in conjunction with social factors and the capacity to self-regulate, underlying physiological parameters may be responsible. Facial expressions can be manipulated in a manner that influences health-relevant patterns of autonomic responding (Ekman & Davidson, 1993; Ekman, Davidson, & Friesen, 1990; Soussignan, 2002). For example, smiling has been shown to improve cardiovascular recovery following administration of a stressor (Kraft & Pressman, 2012) perhaps implying that the *ability* to regulate facial expressions may influence health via direct physiological mechanisms. Similarly, links with HRV indicate that greater regulatory skill may be an outward sign of a more adaptive and flexible autonomic system, facilitating regulatory skills, while concurrently reducing disease risk via better control over physiological activation and recovery.

Although these remain important interpretative possibilities, the present data do not allow for the examination of pathways, nor do they clarify whether indices of expressive flexibility are reflecting a behavioural skill, a more general systemic “flexibility” metric, or underlying capacity/adaptive reserve. It is possible that the effort involved in regulating expressive behaviour may draw on a finite pool of regulatory resource (e.g. Baumeister & Vohs, 2007) and it remains unclear whether flexibility metrics are capturing skill per se or the resources that are available to regulate expressive behaviour. Future work examining whether skills are tapping into underlying adaptive reserve would help to elucidate this possibility.

6.8 Limitations and future directions

Despite the advantages of using an objective behavioural assessment of expressive regulatory skill to test associations with self-reported and more objective indices of physical wellbeing, these data have several limitations. First, the design remains fundamentally cross-sectional, meaning that the direction of the relationships is unclear. Hence, although the ability to flexibly regulate the expression of felt emotion may lead to better health over time, it is equally possible that those with poorer health are less able to regulate due to differences in attention, motivation, or resources. Additionally, findings are based on data from a predominantly white sample, and may not generalise to other ethnic or clinical groups. Furthermore, while our analyses controlled for trait emotion and several other key confounds, it remains possible that unmeasured third variables have influenced findings.

Additionally, although symptom reports are reliable predictors of wellbeing (Barsky, Peekna, & Borus, 2001; Frostholm et al., 2005; Kroenke et al., 1994), they are also subjective, and vulnerable to reporting biases. Given the absence of age differences in symptom reporting, such measures may be better indicators of general wellbeing than actual physical health. Future work investigating more objective and diverse indices of physical health are needed. Likewise, although HRV is indicative of physical health, and corresponds with cardiac risk (Dekker et al., 2000; Thayer et al., 2010), prospective work testing links between expressive skills and clinical health *outcomes* such as the development cardiac or inflammatory conditions is the next step in better understanding the links between expressive skills and physical health. Further, it is unclear whether skills measured in a laboratory paradigm capture real life expressive skill, and it is possible that participants were differentially motivated to follow study instructions regarding expressive regulation. Likewise, the degree to which expressivity measured during the 'natural viewing' condition accurately reflects baseline expressivity is unclear. Future investigations using paradigms in more naturalistic settings, and incorporating realistic social motivators, are needed to develop better understanding of the links between expressive skills and health.

Finally, the effect sizes observed in the present study were modest. Prior work in this area has been based on either student (e.g. Bonanno et al., 2004; Westphal et al., 2010) or clinical (e.g. Rodin et al., 2017; Rosenberg et al., 2001; M. A. Russell et al., 2016) samples, and the diverse age range used in the present study may have made it more difficult to detect effects. Similarly, in an effort to reduce method-related covariation, participants completed baseline questionnaires approximately two weeks prior to attending the laboratory session. This temporal separation reduces the likelihood that acute or momentary confounds (such as changes in state mood or health) influence both predictor and outcome variables, inflating shared variance.

Limitations withstanding, the present report is among the first to provide evidence that an objective, performance based assessment of the ability to up- and down-regulate the expression of both positive and negative emotions is associated with indices of physical health. It is increasingly apparent that rather than being universally beneficial or harmful, the adaptive utility of any regulatory strategy will be largely determined by interpersonal and environmental factors (Bonanno & Burton, 2013; Coifman & Bonanno, 2010; Coifman et al., 2007; Levy-Gigi et al., 2016; Papa & Bonanno, 2008; Westphal et al., 2010). Consequently, the ability to flexibly regulate the expression of emotion in a manner that is most appropriate in any given situation may be a reliable predictor of outcomes. Methodologically, given that expressive skills can be objectively assessed, they are less vulnerable to reporting biases than self-reported strategies. As such, the examination of skills may facilitate the development of alternative, behavioural targets for research and intervention. Overall, the present report provides methodologically rigorous evidence that the *ability* to regulate the expression of felt emotion is associated with both self-reported and objectively assessed health indices. The assessment of expressive skills bypasses many of the limitations inherent in trait and self-reported assessments and may thus offer an objective index of the *capacity* to regulate emotion in a manner which promotes goal attainment, wellbeing, and health.

Chapter 7 : A novel operationalisation of skill

7.1 Preface

The previous chapter presented initial evidence that skill in up- and down-regulating expressions of joy, sadness, and anger appear to be differentially associated with symptom interference and HRV. Although this represents a useful demonstration and extension of prior work, the ability to flexibly regulate the expression of underlying emotion is not the only way of operationalising expressive regulatory skill. As was discussed in Chapters 3 and 4, functionalist accounts suggest that emotional expressions serve signalling functions, frequently occurring in the absence of underlying affect. As such, the ability to signal specific emotions on demand, in the absence of the corresponding feeling state may also be associated with better outcomes. Despite this possibility, few studies have investigated differences in the ability to generate specific emotional expressions when feelings are absent, or tested whether such differences are associated with physical health.

As outlined in the previous chapter, when considering physiological indices that are likely to be associated with skill in signalling specific emotions, HRV offers a useful starting point. Processes involved in the regulation of expressive signals are complex, and necessitate the inhibition of automatic responding, coupled with the activation of both cognitive representations, and facial musculature relevant to the intended signal (Consedine & Mauss, 2014). Put simply, the regulation of emotion hinges upon underlying cognitive, neural and autonomic processes and/or resources.

Although there are several ways in which to index such resources, HRV is increasingly positioned as an objective index of individual differences in the capacity to self-regulate multiple processes, including emotion (Appelhans & Luecken, 2006;

Beauchaine, 2001; Berna et al., 2014; Butler, Wilhelm, & Gross, 2006; Kogan et al., 2014; Oveis, Cohen, et al., 2009; Park, Vasey, Van Bavel, & Thayer, 2014; Porges, 2001, 2007; Thayer & Brosschot, 2005; Thayer et al., 2009; Thayer & Lane, 2000; Thayer & Lane, 2009; D. P. Williams et al., 2015). It therefore seems likely that HRV should be positively associated with the ability to signal specific emotions. However, with the exception of data presented in the previous chapter, work testing links between HRV and emotion regulation has been based on either self-reported regulatory capacity and/or has employed behavioural measures of trait expressivity. As such, it is unknown whether HRV is associated with the *ability* to signal specific emotions.

Within this exploratory context, the present chapter serves two purposes. First, given that HRV is widely interpreted as an objective index of the capacity to regulate emotions, this chapter provides an initial investigation of whether HRV is associated with the ability to signal specific emotions, while concurrently testing the convergent validity between these two distinct means of operationalising objective regulatory capacity. Second, because low HRV is thought to be an independent risk factor for poorer cardiovascular outcomes (Curtis & O'Keefe, 2002; Dekker et al., 2000), investigating the links between HRV and the ability to signal specific emotions may highlight a potential pathway linking regulatory skills with physical health outcomes, thus offering additional support for the possibility that skill-based paradigms predict indices of physical health.

7.2 Citation

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7.3 Abstract

Objective: Vagally mediated heart rate variability (vmHRV) is a measure of cardiac vagal tone, and is widely viewed as a physiological index of the capacity to regulate emotions. However, studies have not directly tested whether vmHRV is associated with the *ability* to facially express emotions. In extending prior work, the current report tested links between resting vmHRV and the objectively-assessed ability to facially express emotions, hypothesizing that higher vmHRV would predict greater expressive skill. **Methods:** Eighty healthy women completed self-reported measures, before attending a laboratory session in which vmHRV and the ability to express six emotions in the face were assessed. **Results:** A repeated-measures analysis of variance revealed a marginal main effect for vmHRV on skill overall; individuals with higher resting vmHRV were only better able to deliberately facially express anger and interest. **Conclusions:** Findings suggest that differences in resting vmHRV are associated with the objectively-assessed ability to facially express some, but not all emotions, with potential implications for health and wellbeing.

7.4 Introduction

Vagally mediated heart rate variability (vmHRV) is derived from the beat-to-beat variation in heart rate and provides an index of vagal activity, autonomic flexibility and inhibitory control (Lane et al., 2009). Because inhibitory control allows for the suppression of automatic responding so that a regulated response can occur (Thayer et al., 2012; Thayer & Lane, 2009), vagal tone is considered a physiological measure of the *capacity* to regulate emotional experiences and expressions (Appelhans & Luecken, 2006; Thayer et al., 2012). Moreover, as the neural regions responsible for both vagal tone and the facial expression of emotion are in close anatomical proximity, the polyvagal theory describes how vagal tone may provide a direct means of assessing the neural capacity to facially signal emotions (Porges, 1997, 2001).

Numerous studies have documented links between vagal tone and emotional expressivity. For example, among infants vagal tone is positively associated with the expression of emotion (Fox, 1989; Stifter & Fox, 1990; Stifter, Fox, & Porges, 1989; Stifter & Jain, 1996), with higher vagal control associated with greater expressivity of interest and joy among 5 month old infants (Stifter et al., 1989). Among adults there is evidence that greater vagal tone predicts fewer self-reported difficulties with emotional clarity (D. P. Williams et al., 2015), greater spontaneous facial expressivity (Lupis, Lerman, & Wolf, 2014), as well as greater self-reported emotional expressivity (Kettunen et al., 2000). However, while vagal tone is increasingly accepted as an index of the ability to express emotions, studies have typically relied on trait and/or self-reported expressivity.

Importantly, models of emotional functioning distinguish between traits, knowledge and skills (Mikolajczak et al., 2015; Mikolajczak, Petrides, Coumans, & Luminet, 2009) and while traits capture tendencies, skills represent capacity or ability. Although prior studies have focused on trait expressivity, both the neurovisceral integration model (Thayer & Lane, 2000), and the polyvagal theory (Porges, 2007) suggest that vagal tone should index the *ability* to facially express emotions. Evidence of links between vagal tone and the control of facial muscle activity (Kettunen et al., 2000), the ability to *recognise* emotional expressions in others (Quintana, Guastella, Outhred, Hickie, & Kemp, 2012), and the ability to enhance and suppress negative emotionality (Demaree, Robinson, et al., 2004) offer some support for the notion that vmHRV might be related to expressive skill.

In one study of particular relevance (Demaree, Schmeichel, et al., 2004), persons with greater vagal tone showed greater "increases" in facial expressivity following instructions to exaggerate expressions in response to negative (but not positive) film stimuli. However, in addition to the need for replication, this single, initial test of objectively-assessed expressive skill is limited in several ways. First, participants were randomized to watch *either* the positive or negative emotion video clips, meaning that differences across emotions may also reflect person variables; scoring multiple emotion expressions for each individual is an obvious solution to this problem. More importantly however, while stimuli validated to elicit specific emotions (disgust and amusement) were used, facial expressions were scored based only on degrees of positive/negative *valence*, without considering the *accuracy* of emotional expressions. As such, while the report offers evidence that vmHRV predicts the *degree* of *negativity* expressed in response to a disgust eliciting film, whether the expressions were any more accurate is unclear, and the question of whether greater vmHRV is associated with a greater ability to express specific emotions is yet to be tested.

The ability to accurately express specific emotional signals is important for several reasons. First, the ability to facially signal a range of contextually appropriate emotions (regardless of internal experiences) is essential for successful social functioning (Ekman, 1973; Ekman & Friesen, 1975; Keltner & Haidt, 1999). Skill deficits will likely interfere with social communication, making it more difficult for a person to manage social relationships, potentially increasing the risk of conflict or isolation, both predictors of worse outcomes (S. Cohen & Wills, 1985; Uchino, 2006). Second, discrete emotional expressions appear to predict a range of outcomes in both infants (Oveis, Gruber, Keltner, Stamper, & Boyce, 2009) and adults, including wellbeing (Harker & Keltner, 2001; Hertenstein, Hansel, Butts, & Hile, 2009; Seder & Oishi, 2012) and mortality (Abel & Kruger, 2010). Third, rather than simply reflecting internal experiences, facial expressions of emotion also *influence* internal processes, including subjective experiences (Laird, 1974) and physiological responding (Demaree, Schmeichel, et al., 2004; Demaree, Schmeichel, et al., 2006; Kraft & Pressman, 2012; Robinson & Demaree, 2007). Given links between emotional facial expressions and physiological, affective, and social outcomes, the next step is to better understand what factors might predict individual differences in expressive skill.

Overall, while vmHRV is a widely accepted index of the capacity to regulate emotional expressions (Demaree, Robinson, et al., 2004; Kettunen et al., 2000; Porges, 2001), studies have yet to provide direct evidence of links between vmHRV and expressive skill. Nonetheless, it seems likely that the ability to accurately express positive and negative emotions in the face will be predicted by greater vagal control. To test this hypothesis, the present report investigated whether the differences in resting vagal control, indexed by vmHRV, would predict differences in the ability to express a range of positive and negative emotions in the face, expecting greater resting vmHRV to predict better expressive skill. The basis for making specific predictions regarding possible vmHRV associated differences in skill across different emotions was lacking in prior work, hence we treat this issue as an exploratory question.

7.5 Methods

7.5.1 Participants

Eighty healthy women were recruited for a study looking at emotions and health. Due to age and sex differences in vmHRV (Liao et al., 1995; Thayer et al., 2012; Verkuil et al., 2015) and other measures not considered in this report, we restricted our sample population to women aged 18-35 who could speak and read English.

7.5.2 Procedures

The local Human Participants Ethics Committee granted ethical approval, and participants signed informed consent before completing online demographic and personality measures (described below). Following this, participants attended a laboratory session during which blood was extracted, before they were fitted with a RS800 CX Polar™ watch heart rate monitor that was worn for the remainder of the testing session. To allow for recovery from any effects associated with venipuncture, participants then completed an online assessment of emotional knowledge, before providing five minutes of baseline, resting heart rate data (approximately 45-60 minutes post-venipuncture). Participants were then seated at a laptop computer and the experimenter read ten target emotion terms aloud. Participants were instructed to pose a genuine expression of the target emotion as rapidly as possible and press the keyboard's spacebar to take a photograph. Following this, a further five minutes of recovery heart rate data were collected before participants were thanked and given a $20 petrol voucher. Blood metrics and emotional knowledge scores are not included in the present report.

7.5.3 Measures

VmHRV. The Polar measurement and analysis system is a valid and reliable method of assessing short-term high frequency heart rate variability (HF-HRV) at rest (Nunan et al., 2009; Quintana, Heathers, & Kemp, 2012). The Polar® RS800CX portable system is comprised of a two lead electrocardiogram (ECG) with electrodes attached to a sensor band which is placed around the chest of the subject at the level of the lower third of the sternum (gel was not used). In the present study successive R–R intervals were recorded in milliseconds during a 5-minute spontaneous breathing and resting 'baseline,' at a sampling frequency of 1000 Hz, providing a temporal resolution of 1ms for each R–R interval. R–R recordings were transferred to a computer via Polar-specific software (Polar® ProTrainer 5 software version 5.35.161). R-R data were de-trended (Smoothness priors, k = 500) (Tarvainen et al., 2014), interpolated at 4 Hz, and artefact corrected (low to medium strength) using *Kubois HRV 2.0* (Tarvainen et al., 2014). An autoregressive spectral analytic approach was employed for the frequency domain measurements using model order 16 (Boardman et al., 2002). The percentage of R-R intervals that differed by greater than 50 milliseconds (PNN50), the root mean square of successive differences (RMSSD), and autoregressive high frequency HRV were calculated. In the present report RMSSD, PNN50 and autoregressive high frequency HRV were all highly correlated (all r values > 0.90, all p values < .001*),* therefore we report vmHRV results using RMSSD, a time-domain measure of vmHRV that is valid (Thayer & Sternberg, 2010), stable (Li et al., 2009), and primarily reflects trait influences (Bertsch et al., 2012). The present report did not control for respiration as it has been suggested that this is not necessary when breathing spontaneously (G. F. Lewis et al., 2012; Thayer et al., 2011). Due to an equipment failure six consecutive participants had missing vmHRV data, so were excluded from analysis, as were two outlyers, identified as having RMSSD scores more than three standard deviations above the mean, resulting in a final sample size of 72.

Expressive Skill. Participants were instructed to facially express a series of emotions (joy, sadness, guilt, embarrassment, fear, contempt, anger, surprise, disgust, and interest) in a standardized order as quickly and accurately as possible. To prevent the metric being confounded via the use of unmeasured, internal regulatory strategies, participants were only given five seconds to express each emotion. Two coders independently scored expressive accuracy on a four point scale ranging from 1 (not at all accurate) to 4 (very accurate), and expressive intensity on a 0 (not at all intense) to

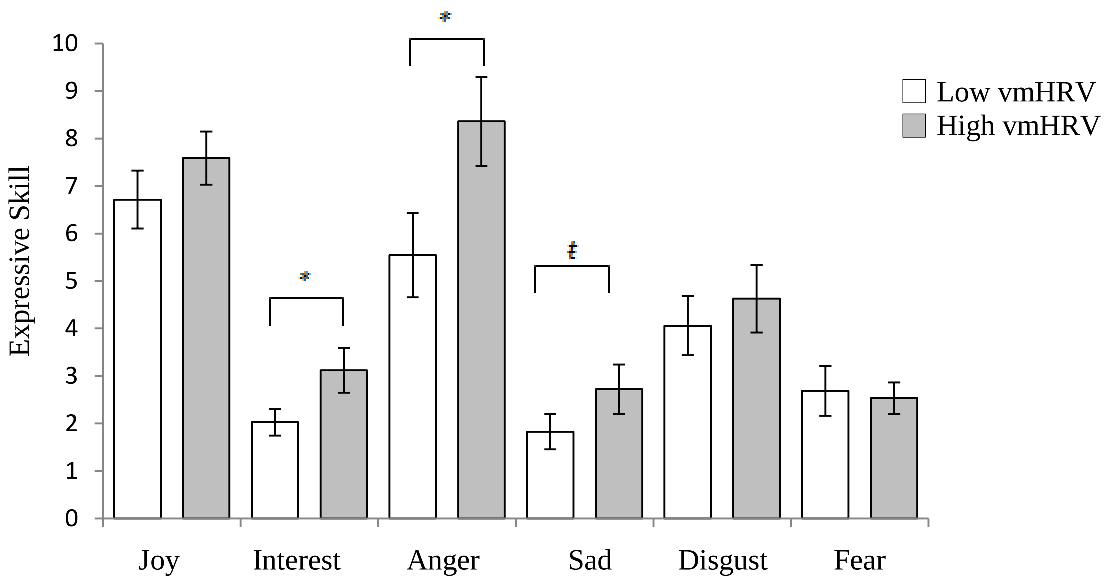
3 (very intense) scale. Cohen's kappa ranged from $\varkappa = .58$ to $\varkappa = .86$ with a mean $\varkappa = .74$. Accuracy and intensity scores were multiplied to generate an overall expressive skill score for each emotion. For the present report we elected to focus on five fundamental basic emotions; joy, sadness, anger, disgust, and fear (Ekman, 1992, 1999), with the addition of interest which was included to provide greater positive/negative balance. The present report focused on these emotions because they are developmentally primary (Ekman, 1999), and are characterised by distinct and universal subjective experiences, motivational properties, physiological responses, and expressive signals (Ekman, 1999); surprise was excluded as there is less evidence to support surprise as a basic emotion (Ekman, 1992), and it does not have a clear positive or negative valence. Interest was included as an additional positive valenced emotion as it is considered by some to also be a basic emotion (Frijda, 1986; Izard, 1992; Tomkins, 1984), it serves a motivational and adaptive function across the lifespan (Sansone & Smith, 2000), and occurs in tandem with distinct physiological changes and facial expressions (Langsdorf, Izard, Rayias, & Hembree, 1983; Reeve, 1993; Silvia, 2005).

7.5.4 Analytic Strategy

A repeated-measures, mixed model analysis of variance (ANOVA) was used to test whether differences in resting vmHRV would predict the ability to facially express six emotion expressions. As Mauchly's test indicated the presence of a sphericity violation (χ^2 (14) = 71.76, $p < .05$), we elected to use the Greenhouse–Geisser estimate ($\varepsilon = .69$), and report uncorrected degrees of freedom and corrected p values as per recommended guidelines (Jennings, 1987). Follow-up independent samples t-tests were used to identify the specific expressive skills that differed as a function of high versus low resting vmHRV.

7.6 Results

A 2 (high/low baseline vmHRV) by 6 (emotion) repeated-measures ANOVA revealed a significant main effect for emotion (F (5, 350) = 38.87, p < .001, sr^2 =.36), and a marginal main effect for resting vmHRV, (F (1, 70) = 3.49, p =.066, sr^2 = .05); as expected, those with higher vmHRV had marginally greater expressive skill scores overall. Although the multivariate interaction effect was non-significant (F (5, 350) = 1.88, p > .05, sr^2 = .03), follow-up directional t-tests indicated that persons with higher resting vmHRV demonstrated greater skill in expressing anger (t (70) = -2.18, p < .05), and interest (t (70) = -1.99, p < .05), and, marginally greater skill in expressing sadness (t (70) = -1.38, p < .10). Contrasts for joy, fear and disgust were not significant (Figure 7.1).



*p < .05, ŧ p < .10

Figure 7.1: Bar chart showing means and standard errors of expressive skill scores as a function of dichotomized baseline vagally mediated Heart Rate Variability

7.7 Discussion

The present report examined links between vmHRV and an objective, performance-based assessment of expressive skill. Although vmHRV is widely considered an index of the *capacity* to regulate cognitive and emotional processes, demonstrations of links between vagal tone and objectively assessed expressive skill have been few. Based on characterizations of vmHRV, and its links to better performance in other forms of regulation, along with evidence that both vagal tone and facial musculature are innervated by adjacent neural regions (Porges, 1997), we predicted that individuals with higher resting vmHRV would be better able to deliberately express emotions in the face. This hypothesis was partially confirmed; participants with higher resting vmHRV indexed marginally greater overall expressive skill than those with lower vmHRV, although differences were only significant for some emotions[2]. Below, we discuss these results more fully, consider how they supplement

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[2] *In addition to the published results presented in this chapter, linear regression models were run to test for potential moderating effects of ethnicity. For each model, HRV was entered in the first step, followed by a binary ethnicity score (European/NZ European vs non-European/NZ European), followed by the HRV*ethnicity interaction term. Analyses indicated that there was no evidence for ethnicity-based moderation in the links between HRV and expressive skill in this sample. However it is likely that the sample was not sufficiently diverse to reliably test for this possibility, (European/NZ European = 73.6%), and artificially clustering non-European/NZ European ethnic groups into a single category is likely to obscure differences. Further work is thus needed to test for the possible moderating effects of ethnicity and/or culture.*

current thinking about vmHRV as an index of regulatory capacity, and consider directions for future study.

As was noted above, while vmHRV is widely considered to be an index of regulatory *ability*, prior work investigating links between vagal tone and affective outcomes has either been based on trait or self-reported outcomes such as positive emotionality (Kok & Fredrickson, 2010), self-reported regulation (D. P. Williams et al., 2015), or trait expressivity (Kettunen et al., 2000; Lupis et al., 2014). Although studies attempting to assess links between vagal tone and expressive skill have documented links between vmHRV and the control of facial muscle activity (Kettunen et al., 2000), the ability to recognize expressions in others (Quintana, Guastella, et al., 2012), and greater (negative) expressive valence in persons with higher vagal tone (Demaree, Robinson, et al., 2004), the present report is among the first to specifically show preliminary evidence of a link between resting vmHRV and the objectively assessed ability to facially express emotions.

More broadly, this study adds to a growing body of work documenting links between physiological parameters and emotion expressivity; although marginal, evidence of a relationship between objectively assessed expressive skill and resting vmHRV adds methodologically-rigorous support to the claim that vmHRV may index the ability to signal emotions on demand. Given that facial expressions of emotion have been associated with numerous outcomes including wellbeing and mortality (Abel & Kruger, 2010; Harker & Keltner, 2001), the ability to signal emotions may confer an adaptive advantage to those with higher vmHRV (e.g. Kogan et al., 2014). Indeed, greater skill in signalling emotions in the face is one possible mechanism by which vmHRV may predict to better outcomes across the lifespan. Conversely, relatively lower vmHRV may be associated with expressive skill deficits which are associated with poorer outcomes (Gaebel & Wölwer, 1992; Girard, Cohn, Mahoor, Mavadati, & Rosenwald, 2013; Gupta & Bonanno, 2011; Trémeau et al., 2005).

It is unclear whether the possible expressive skill advantage evident among those with greater resting vmHRV is comparable across all emotion signals. Prior work has implied that the links between emotional expressions and vmHRV were limited to negative valenced expressions (Demaree, Robinson, et al., 2004). In contrast, the current data indicate that higher vmHRV may have links to skill in expressing both positive (interest) and negative (anger) emotions. More broadly, although the multivariate interaction term was non-significant and our data are clearly in need of replication, follow-up testing suggesting differences for expressions of anger, interest, and possibly sadness (but not fear, disgust or joy) is provocative. One possibility is that a measurement issue underpins these findings, with the more difficult emotions (as indicated by overall lower means) being non-significant. However, as is evidenced in Figure 7.1, although interest expressions had low mean skill scores, it nonetheless varied between the high and low vmHRV groups, whereas joy had a comparatively high mean score, but did not differ between groups. An alternative possibility is that emotions that are more commonly expressed in the daily lives of the sample more readily reveal differences. There is some evidence that fear is less commonly experienced than other emotions (Scherer & Tannenbaum, 1986). Work using experience sampling found that of twelve emotions measured, fear and disgust were the least frequently experienced and fear the least intensely experienced emotion (Zelenski & Larsen, 2000), however, again, an absence of links between expressing joy and vmHRV does not support this interpretation. Nonetheless, the question of which specific expressions are associated with differences in resting vmHRV, and in which direction, will be important for future studies.

A further question of importance regards the mechanisms that link greater vmHRV to greater expressive skill. Although not directly assessed, one possibility is that a common biopsychosocial mechanism underlies both vagal tone and expressive skill. In this interpretation, low vmHRV might be seen as an endophenotype for a range of dysfunctions involving physiological, cognitive, and affective regulation (Porges, 1997; Thayer & Lane, 2009). As such, greater expressive skill may directly reflect a more flexible and adaptive regulatory system that is able to effectively adjust automatic responding and appropriately employ cognitive and physiological resources. Designs examining interventions aimed at improving vmHRV, and testing for subsequent changes in regulatory skill, or vice versa, are needed to test this possibility.

Alternatively, expressive skill may index a broader constellation of skills in the area of social functioning. Persons with greater expressive skill may be more effective at signalling in a manner that elicits social support and/or manages interpersonal interactions and conflict more effectively (Harker & Keltner, 2001; Keltner & Haidt, 1999; Kogan et al., 2014). Greater control over emotion expressivity may facilitate social relating and consequently act to buffer the impact of daily stressors on health (Uchino, 2006). There is considerable evidence that social support parameters are related to more adaptive biological profiles across cardiovascular, neuroendocrine, and immune systems (Kogan et al., 2014; Kok & Fredrickson, 2010; Uchino, 2006). Models testing the degree to which expressive skill may mediate or moderate links between vmHRV and social outcomes would help to test this possibility.

7.8 Limitations and future directions

Although providing preliminary evidence that more adaptive patterns of resting vmHRV are marginally associated with a greater overall ability to facially express emotions is a useful contribution, the current study has several limitations. First, the absence of a significant overall effect for vmHRV must be acknowledged, and it is possible that the small and homogenous sample of young women made it difficult to detect effects. Relatedly, data may or may not be generalizable to more diverse groups. Additionally, the ability to generate a genuine expression of emotion in a contrived setting may reflect only some aspects of real world expressive skill; knowing which emotions are appropriate to which context, and having emotional responses that fit social and cultural expectations is also likely important (Consedine, Chentsova-Dutton, & Krivoshekova, 2014). These data merely show that vmHRV predicts greater expressive skill for some emotions (as indexed by this paradigm) and although they offer early evidence and proof of principle that vmHRV may be associated with objectively-assessed expressive skill, replication in other samples, using other skills, and in other contexts is warranted. Finally, the cross-sectional nature of these data mean that it is not possible to determine whether the link between expressive skill and vmHRV reflects the impact of vmHRV on affective signalling, or whether better expressive skill serves a protective function, preserving or enhancing autonomic flexibility over time. While it seems likely that expressive skill is the *result* of more flexible autonomic and physiological systems, it is also possible that that better expressive skill influences physiological functioning, buffering a person against external stressors via social mechanisms; further work addressing the direction of the relationships is warranted.

Despite these limitations, the present report provides early evidence that resting vmHRV predicts objectively assessed expressive regulatory skills for some emotions. To get beyond the limitations imposed by self-reported trait measurement, researchers must develop novel, face-valid, and portable means of indexing such skills. Given that the ability to express a range of emotions in the face (regardless of internal emotional experience) is pivotal in successful social functioning, the expressive skill task provides a cost effective, portable, and face-valid measure of expressive abilities. As such, further studies using expressive skill paradigms to examine links between emotion regulation, physiological functioning, and mental and physical health outcomes are warranted.

Chapter 8 : Expressive skills and self-rated health, wellbeing, and immune parameters

8.1 Preface

The previous two chapters have demonstrated that; a) the ability to flexibly regulate expressions of joy, sadness, and anger predict symptom interference and HRV, and b) individuals with higher HRV are better able to deliberately signal some discrete emotions in the face, likely in the relative absence of underlying emotion. However, despite offering early evidence that objective, skill-based metrics predict physical health parameters, several limitations must be considered.

First, findings from Chapter 7 suggest that higher HRV predicts greater skill in some aspects of a novel expressive skill task (i.e., those with higher HRV were better at signalling some emotions in the absence of underlying feeling). From a regulatory perspective this task is fundamentally different from skill in up- and down-regulating felt emotion, and it is unclear whether this more portable, rapid, and potentially automatable operationalisation of expressive skill will also predict more direct indices of physical health. As discussed earlier (Chapter 7), functionalist accounts suggest that signalling a range of emotions, regardless of underlying affect, is central to successful social functioning (Blair, 2003; Fridlund, 2014; Hareli & Hess, 2012). As such, it seems likely that the ability to accurately express emotions should be associated with a range of better outcomes. However, although HRV is a marker of autonomic flexibility (Thayer & Lane, 2000) that is *associated* with better physical health (Dekker et al., 2000; Thayer et al., 2012), higher versus lower HRV does not necessarily map directly onto physical health status: it is a proxy variable. As such, links with HRV alone do not provide sufficient evidence that expressive skills predict physical health outcomes. If the operationalisation is to be useful, associations should be apparent across multiple physical, biological, and self-reported health domains. Hence, in extending documented links between HRV and expressive skill, the present chapter tests whether the ability to signal specific emotions in the face is also associated with self-reported health and wellbeing, along with biological indices of physical health.

Second, although the tripartite model of emotion regulation is comprised of regulatory traits, knowledge, and skills (see Chapter 4), the empirical work presented thus far has been limited to the investigation of expressive regulatory skills; the possibility that emotional knowledge acts as a confound or will concurrently predict physical health outcomes has not yet been tested. Prior evidence suggests that self-reported knowledge predicts better health-related quality of life (Extremera & Fernández-Berrocal, 2002), fewer symptoms and lower illness counts (Goldman, Kraemer, & Salovey, 1996), better general health and health behaviours (Tsaousis & Nikolaou, 2005), lower prescription drug consumption and fewer doctor visits, hospitalisations, and days spent in hospital (Mikolajczak et al., 2015). Furthermore, greater self-reported knowledge is associated with lower cortisol secretion during stressful situations (Mikolajczak, Roy, Luminet, Fillee, & de Timary, 2007), potentially influencing inflammatory profiles and subsequent disease risk (Libby, Ridker, & Maseri, 2002).

However, as with self-reported trait regulation, self-reported knowledge is subject to the same reporting biases that were discussed in Chapter 3. Evidence suggests that people are generally poorly equipped to estimate their own abilities (e.g. Paulhus, Lysy, & Yik, 1998). Furthermore, because self-reported knowledge is moderately to highly correlated with personality factors and general wellbeing (Brackett & Mayer, 2003), self-reported knowledge metrics may involuntarily index constructs such as optimism and emotional stability. As with trait suppression and negative affect, it is possible that third variable confounds may be responsible for any links between self-reported emotional knowledge and physical health outcomes.

As a result of these limitations, theoretical work has differentiated between trait- and ability-based measures of emotional knowledge, with some arguing that emotional knowledge is best positioned as a form of intelligence that is most appropriately assessed using objective, maximal-performance tests (Brackett & Mayer, 2003; Mayer, Caruso, & Salovey, 1999). Evidence suggests that trait and ability-based measures of emotional knowledge/intelligence are only weakly or moderately correlated (Brackett & Mayer, 2003) and, when compared with trait assessments, ability metrics show better discriminant validity from wellbeing and personality constructs (Brackett & Mayer, 2003).

Despite the methodological and conceptual advantages of ability-based knowledge/intelligence metrics, work testing links between emotional intelligence and health has thus far been limited to self-reported assessments. As with expressive skills, the question of whether objective, performance-based tests will also predict physical health outcomes is unknown. In addressing this gap in the literature, the report presented in this chapter also tests whether objective measures of emotional intelligence are associated with biological parameters and self-reported health and wellbeing.

Finally, although the previous chapters have found that expressive regulatory skills are associated with self-reported symptom interference and HRV, recent years have seen a burgeoning interest in the potential role of immune parameters in the links between emotion regulation and health (Appleton, Buka, Loucks, Gilman, et al., 2013; Demarble, Moskowitz, Tardif, & D'Antono, 2014; Jaremka et al., 2013; Kitayama et al., 2015). In brief, it is thought that exposure to daily stressors activates the immunoregulatory system, producing acute elevations in inflammatory markers. Although adaptive in the short-term, chronic or repeated exposure to stress can dysregulate this system and increase the risk of sustained systemic inflammation, a risk factor in the development of inflammatory disease (Hansson 2005; Libby et al., 2002; Sjöholm & Nyström, 2006; Willeit et al., 2016; Yudkin, Kumari, Humphries, & Mohamed-Ali, 2000).

Given that the capacity to regulate expressivity appears to protect against psychological distress (Levy-Gigi et al., 2016) and contribute to better psychological adjustment (Bonanno et al., 2004; Gupta & Bonanno, 2011; Westphal et al., 2010), it is possible that regulatory skills will also reduce vulnerability to daily stressors, and the subsequent risk of dysregulated inflammatory activity. However, although prior work has suggested that individual differences in emotion regulation may influence health via inflammatory processes (e.g. Appleton, Buka, Loucks, Gilman, et al., 2013; Mikolajczak et al., 2007; Willeit et al., 2016), interpretations of prior data are restricted by the traditional limits of self-report (see Chapter 3). Whether objective tests of expressive ability and/or emotional knowledge are also associated with inflammation is unknown. Accordingly, the present chapter extends evidence of links between expressive skills and both self-reported health and HRV by testing whether emotional knowledge, and/or the ability to signal emotions is associated with a range of immune parameters that are indicative of underlying inflammation.

In summary, the present chapter serves three functions. First, by testing whether the ability to signal specific emotions is associated with a broader range of outcomes, it extends the links with HRV reported in Chapter 7 and offers further evidence for the predictive validity of this novel operationalisation of expressive skill. Second, this chapter presents an initial investigation of possible links between the knowledge component of the tripartite model of emotion regulation (Chapter 3) and physical health outcomes. Finally, in extending links towards a potential mechanism it investigates whether skills in expressing specific emotions and/or emotional knowledge are associated with a range of immunoregulatory molecules.

8.2 Citation

Tuck, N. L., Grant, R. I., Jackson, A. S., Brooks, A., & Consedine, N. S. (2016). Beyond self-report: performance measures of emotional competencies predict symptoms of depression and anxiety, physical symptoms, self-rated health and immunoregulatory molecules. Annals of Behavioral Medicine. doi:10.1007/s12160-016-9809-5

8.3 Abstract

Background: Most work testing links between emotional competencies and health has focused on self-reported and/or trait assessments. However, more objective assessments of skills and knowledge may also predict health relevant outcomes. **Purpose:** The current study investigated whether performance-based tests of emotional knowledge and expressive skill predicted symptoms of depression and anxiety, self-reported physical symptoms, perceived health, and a range of immunoregulatory molecules. **Methods:** Eighty females aged 18-35 completed self-report assessments before attending a testing session in which they provided blood samples and completed performance-based assessments of expressive skill and emotional knowledge. **Results:** Greater expressive skill predicted better self-reported outcomes but links to immunoregulatory molecules were mixed. Expressive skill for contempt and anger predicted higher, whereas skill for happiness predicted lower, concentrations of immunoregulatory molecules. **Conclusions:** These data highlight the

need to extend research beyond self-reported emotional competencies and suggest that performance-based skill and knowledge metrics may be associated with health relevant outcomes.

8.4 Introduction

Emotional competencies (ECs) reflect individual differences in the ability to perceive, understand and regulate both the experience and the expression of emotions (Mikolajczak et al., 2015). The tripartite model of ECs distinguishes between traits, knowledge, and skills (Mikolajczak et al., 2015; Mikolajczak et al., 2009), with trait ECs representing the way in which individuals typically behave, knowledge capturing what individuals know or understand about their own and others' emotions, and skills referring to what individuals are capable of doing (Mikolajczak et al., 2015). For example, a person may often smile (trait) and know that he/she should look happy when congratulating a colleague for a promotion (knowledge), but may, or may not, be able generate a convincing smile in the moment (skill). Importantly, although traits, knowledge and skills are related, they are also distinct. For example, knowledge regarding how to best regulate emotional experiences or expressions does not always translate into the ability to do so (Mikolajczak et al., 2015).

Although numerous ECs have been associated with health, a substantial body of work has focused on emotional expressivity, with expressive difficulties being consistently linked to worse outcomes. For example, self-reported difficulties with expressing anger have been shown to predict heart disease risk (Haynes et al., 1980), the Type D personality (high negative affect and low expressivity) is associated with poorer health outcomes (Denollet, Pedersen, Vrints, & Conraads, 2006), and alexithymia (characterized by difficulties with emotional expression) is a risk factor for greater physical symptoms and illness behavior (Lumley, 2004). The tendency to express emotions in the face also appears to predict outcomes, with one study reporting that greater facial expressivity predicted lower symptom counts (Malatesta, Jonas, & Izard, 1987), whereas the tendency to express more positive affect during a structured interview has been associated with reduced risk of developing heart disease over a 10-year period, even after controlling for coronary risk factors and trait negative affect (Davidson et al., 2010).

Although informative, most work investigating links between emotional expressivity and health has focused on either trait expressivity, or perceived expressive skill. However, skills can be assessed using more objective, performance-based tests, which are less vulnerable to reporting biases and/or method related co-variation with third variable confounds (Podsakoff et al., 2012). These advantages, together with established links between *trait* expressivity and health (Davidson et al., 2010; Lumley, 2004; Malatesta et al., 1987), suggest that investigating whether the *ability* to express emotions also predicts outcomes is both methodologically advantaged, and addresses a clear gap in the literature.

Although numerous expressive skill-based competencies might predict health, the ability to express emotions in the face offers a good starting point. The ability to facially signal emotion develops across childhood, is universal, and occurs on a near continuous basis in social environments (Oster & Ekman, 1978). It is thought that emotional expressions evolved to facilitate interpersonal encounters, and the ability to facially express emotions is central to successful social functioning (Consedine, Magai, & Bonanno, 2002; Ekman, 1992; Field & Walden, 1982; Halberstadt, Denham, & Dunsmore, 2001; Keltner & Ekman, 2000). Additionally, although few studies have investigated links between expressive skill and health, there is evidence that the ability to up- and down-regulate facial expressions prospectively predicts better psychological adjustment among adults (Bonanno et al., 2004; Westphal et al., 2010) and greater positive affect and extroversion among children (Custrini & Feldman, 1989; Zuckerman & Przewuzman, 1979). Conversely deficits in expressive skill are evident among maltreated mothers and their children (Camras et al., 1988), as well as among persons suffering from complicated grief (Gupta & Bonanno, 2011) and depression (Gaebel & Wölwer, 1992; Trémeau et al., 2005).

However, much of this work has focused on spontaneous expressivity in response to stimuli, which may be best conceptualized as indexing *trait* expressivity rather than expressive skill. Additionally, prior work has not directly tested links between skill and health indices, and has typically focused on differences between diagnostic groups (i.e. schizophrenics versus depressives) or in psychopathologies (Davies et al., 2016). Finally, those studies that have examined expressive skill among healthy adults have focused on the *strength* of emotional signals (Bonanno et al., 2004) without investigating the ability to *accurately* express specific emotions. Given the distinction between 'volume' and 'fidelity' in emotion signalling, the current study investigated whether the ability to accurately express specific emotions in the face was associated with a range of self-reported and biological outcomes.

Along with skills, the knowledge component of the tripartite EC model can also be assessed with performance-based metrics, and has been under-studied in terms of links to health. For example, one meta-analysis identified five studies assessing links between perceived emotional knowledge and physical health (Schutte, Malouff, Thorsteinsson, Bhullar, & Rooke, 2007), with evidence that greater knowledge predicted higher health-related quality of life (Extremera & Fernández-Berrocal, 2002), fewer symptoms, lower illness counts (Goldman et al., 1996), and better general health and health behaviors (Tsaousis & Nikolaou, 2005). However, these studies were based on self-reported knowledge and self-reported health, whereas evidence suggests that EC knowledge may also predict more objective health indices. For example, there is evidence that self-reported EC knowledge impacts cortisol secretion during stressful situations (Mikolajczak et al., 2007) which, over time, may influence inflammatory profiles and subsequent disease risk (Libby et al., 2002). Additionally, two large studies (N = 1,310, and N = 9,616) found that self-reported EC knowledge predicted numerous objective health indices, including prescription drug consumption, doctor visits, number of hospitalizations, and days spent in hospital, with EC knowledge attenuating and, in some cases, compensating for known risk factors (Mikolajczak et al., 2015).

However, conceptualizing emotional knowledge as a form of intelligence makes it theoretically distinct from self-reported knowledge and necessitates objective, performance-based assessment (Brackett & Mayer, 2003; Mayer et al., 1999). The Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) is the most widely used performance test of emotional knowledge, and although there is evidence that scores are associated with outcomes including depression (Salguero, Extremera, & Fernández-Berrocal, 2012) and anxiety (Jacobs et al., 2008), there are few, if any, studies investigating whether performance tests of emotional knowledge are associated with physical health. Therefore, in extending prior work linking perceived knowledge with health indices (Mikolajczak et al., 2015; Peña-Sarrionandia et al., 2015), the present report evaluated whether this objective, performance-based test of emotional knowledge predicted a range of self-reported and objective health relevant outcomes.

In terms of health outcomes, studies investigating links between ECs and health have begun to test the possibility that emotions may impact health via changes in patterns of immunoregulatory molecules (Appleton, Buka, Loucks, Gilman, et al., 2013). Emotional experiences orchestrate changes in physiological and biological systems, influencing circulating pro-inflammatory cytokines (Mauss et al., 2005). This relationship appears to be bi-directional, and although negative emotionality may sensitize inflammatory responding (R. Glaser, Robles, Sheridan, Malarkey, & Kiecolt-Glaser, 2003; Maes, Ombelet, De Jongh, Kenis, & Bosmans, 2001), inflammatory-cytokines also influence mood, cognition and behaviour (Maier, 2003). This is because stressors and emotions work in tandem to activate the hypothalamic–pituitary–adrenal (HPA) axis and/or the sympathetic nervous system (SNS). For example, perceived threat may produce a fearful and/or hostile emotional response, which activates the HPA axis to release pituitary and adrenal (stress) hormones which alter the production of pro-inflammatory cytokines, preparing the organism to respond to environmental threats. Although adaptive in the acute phase, prolonged or amplified activation of these systems can dysregulate inflammatory responding (R. Glaser et al., 2003; Maes et al., 2001).

For example, hostility has been linked to a range of inflammatory markers including tumour necrosis factor (TNF), interleukin-6 (IL-6), and C-reactive protein (CRP) (Demarble et al., 2014; Ranjit et al., 2007), and meta-analyses have confirmed dose–response relationships between depression and CRP, IL-6 (Howren, Lamkin, & Suls, 2009) and TNF (Dowlati et al., 2010). Additionally, TNF appears to fluctuate in tandem with positive and negative mood inductions (Mittwoch-Jaffe, Shalit, Srendi, & Yehuda, 1995) and has been linked to both shame (Dickerson, Kemeny, Aziz, Kim, & Fahey, 2004) and alexithymia (Bruni et al., 2006). Along with these well studied pro-inflammatory cytokines, interferons may also be implicated in affective processes, with evidence that the administration of interferon-gamma (IFN-γ) can evoke depressed mood (Jett et al., 1994), with concentrations declining in response to antidepressant treatment (Connor & Leonard, 1998). Conversely, interleukin-4 (IL-4) regulates IFN-γ production and has been associated with alexithymia (Corcos et al., 2004) and reduced serotonin uptake, potentially influencing multiple affective, cognitive, and physiological processes (Mössner, Daniel, Schmitt, Albert, & Lesch, 2001).

In turn, these immunoregulatory molecules influence long term disease risk. For example, IL-6 and TNF promote the production of CRP (Ikonomidis, Stamatelopoulos, Lekakis, Vamvakou, & Kremastinos, 2008), an established predictor of coronary artery disease (Danesh et al., 2004). These cytokines, along with IL-8 are central to the development and progression of atherosclerotic plaques in the arterial wall (Ikonomidis et al., 2008), independently predicting cardiovascular disease (CVD) risk in healthy subjects (Libby et al., 2002), and coronary mortality among patients with CVD (Koukkunen et al., 2001).

As such, emotional competencies may impact health via patterns of inflammatory responding and subsequent vulnerability to inflammatory disease (Black & Garbutt, 2002; DeSteno et al., 2013; R. Glaser & Kiecolt-Glaser, 2005). Although most work has focused on trait emotionality, it is also possible that the *ability* to express emotions is associated with immune parameters in several ways. First, expressive skill may index underlying affect, whereby individuals become more skilled at expressing those emotions that they signal most frequently (or vice versa; persons may favor those emotions that they are 'good' at). If this is the case, then skill for expressing positive (as opposed to negative) emotions may index the frequent or prolonged experience of positive (versus negative) emotionality, which is differentially associated with more adaptive patterns of inflammation (DeSteno et al., 2013; R. Glaser et al., 2003; Jaremka et al., 2013).

Alternatively, rather than showing divergent links for positive and negative expressions, greater skill may index physiological and cognitive flexibility, whereby the ability to accurately communicate both positive *and* negative emotions reflects a more adaptive, flexible, and responsive system (Lane et al., 2009; Thayer & Lane, 2000). In theory, being able to effectively communicate the signal aspect of a range of emotions should facilitate goal attainment and improve social relationships, potentially attenuating the inflammatory stress response or buffering against the impact of daily stressors. If this is the case, then expressive skill for both positive and negative emotions should be associated with better outcomes (Bonanno et al., 2004). However work to date has not tested either of these possibilities.

The current study

The present report was designed to test whether links between ECs and health extend beyond traits, to encompass performance-based assessments of emotional knowledge and expressive skill. In addition to self-reported depressive symptoms, anxiety, symptom reports, and perceived self-rated health, the present report tested whether emotional knowledge and expressive skill would predict concentrations of a range of immunoregulatory molecules including pro-inflammatory cytokines; IL-6, IL-8, and TNF, the acute phase protein CRP, and IL-4 and IFN-γ, while controlling for known bio-behavioral and demographic confounds (Connor & Leonard, 1998). It was expected that greater expressive skill and knowledge would predict better outcomes, as indexed by fewer depressive symptoms, lower trait anxiety, fewer reported symptoms and better self-rated health, and that these differences might extend to immunoregulatory molecules.

8.5 Methods

8.5.1 Participants

Eighty female participants were recruited via social media, email, poster and flier advertising for a study on emotions and health. Due to age and sex differences in concentrations of inflammatory molecules (Ferrucci et al., 2005; Hung, Knuiman, Divitini, Davis, & Beilby, 2008; Rohleder, Schommer, Hellhammer, Engel, & Kirschbaum, 2001; Wörns, Victor, Galle, & Höhler, 2006), we restricted our sample population to females aged 18-35 that could speak and read English.

8.5.2 Procedures

Participants signed informed consent - approved by the local ethics board - before completing online demographic, health and personality measures. Participants then attended a laboratory session, during which they provided blood samples before being fitted with a Polar™ watch heart rate (HR) monitor which was worn for the remainder of the session. Participants then completed a standardized performance-based test of emotional knowledge (the MSCEIT) followed by the expressive skill task. For the expressive skill task, participants were seated at a laptop computer while the experimenter read 10 target emotion terms aloud in a standard order. Participants were instructed to pose a genuine expression of the target emotion as rapidly as possible and press the computer's spacebar key to take a photograph. Following this, five minutes of resting HR data were collected before participants were thanked and given a $20 petrol voucher. HR data are not included in the present report.

8.5.3 Measures

Income: Household income was measured in New Zealand Dollars (NZD) and scored as being less than or equal to NZD $39,000, $40-$ 99,000, and $100, 000 and above (see Table 8.1).

Table 8.1: Sample Characteristics

	%	Range	Mean	SD
Age		18 - 35	24.54	4.58
BMI		16.30 - 33.14	22.59	3.39
Diagnoses		0 - 4	0.76	0.98
Progesterone		1 - 3	2.19	0.83
Physical Activity		0 - 7	4.01	2.45
Household income in NZD				
≤ $40,000	37.50			
$40 - $100,000	31.25			
≥ $100,000	31.25			
Ethnicity				
European & NZ European	71.30			
Maori & Pacific	2.50			
Asian, Indian & Sri Lankan	22.50			
Mixed Asian & European	3.80			

Ethnicity Participants indicated their ethnicity as European or NZ European, Asian, Indian, Sri Lankan, Maori, Pacific, European-Asian, or Other. Responses were dummy coded as 0 = 'White' (NZ European/European, 71%) and 1 = 'non-White' (all others, 29%) (see Table 8.1)

Marital Status Participants indicated whether they were single, married or in a relationship, or divorced, separated or widowed (see Table 8.1).

Depressive Symptoms: The Centre for Epidemiologic Studies Depression Scale (CES-D) is a 20-item self-reported measure of depressive symptoms designed to be used in the general population (Radloff, 1977). The CES-D has good reliability (Knight, Williams, McGee, & Olaman, 1997; Orme, Reis, & Herz, 1986) and its validity as a measure of depression has been confirmed in community studies of adults (Santor, Zuroff, Ramsay, Cervantes, & Palacios, 1995) and clinically depressed individuals (Boyd, Weissman, Thompson, & Myers, 1982). In the present study $\alpha = .88$.

Anxiety: The trait version of the State-Trait Anxiety Inventory (STAI) (L. Spielberger, 1986) contains 20 items such as 'I feel like a failure' and 'I feel secure' (reverse scored), on which participants rate how they generally feel on a 4-point scale ranging from 1 (Almost Never) to 4 (Almost Always). The trait-STAI has a replicable factor structure and good psychometric properties (Oei, Evans, & Crook, 1990). In the current study $\alpha = .93$.

Symptom Reports: Participants indicated the presence/absence and severity of symptoms across the past two weeks on a scale from 1 (not present) to 4 (present and severe) using the 42-item Physical Symptoms Inventory (PSI) (Wahler, 1968), which includes items such as "feeling tired" and "dizzy spells". A further 20 commonly experienced symptoms were added to this list, including items such as 'cough,' 'abdominal pain,' and 'difficulty concentrating'. The scores for each participant were averaged to provide a mean symptom score ranging from 1.00 – 2.58, ($\bar{x}$ = 1.30, SD = .27), $\alpha = .82$.

Self-rated health: Participants responded to the single item; "Would you say your health in general is excellent, very good, good, fair, or poor?" This is a frequently used index of perceived self-rated health that has been shown to independently predict mortality (Idler & Benyamini, 1997). Scores were numbered from 1 (poor) to 5 (excellent), and in the present sample; ($\bar{x}$ = 3.5, SD = .98).

Expressive Skill: Participants posed facial expressions (happy, sad, guilty, embarrassed, afraid, contemptuous, angry, surprised, disgusted and interested) as quickly and accurately as possible. To limit the use of unmeasured, experiential regulatory strategies, participants were only given five seconds for each pose. Two coders independently scored expressive accuracy on a four point scale ranging from 1 (not at all accurate) to 4 (very accurate) and expressive intensity on a 0 (not at all intense) to 3 (very intense) scale. Cohen's kappa ranged from $\varkappa = .58$ to $\varkappa = .86$ with a mean $\varkappa = .74$. These scores were then multiplied to generate an overall score for each emotion, and individual scores were averaged to generate an overall expressive skill score ($\alpha = .90$).

Emotional Intelligence: The MSCEIT (Mayer, Salovey, & Caruso, 2002) is a performance-based measure of emotional knowledge, developed in the intelligence testing tradition. Structurally, the MSCEIT is complex, and although various groups have reported different factor structures and generalizability (Conte, 2005; Landy, 2005), the MSCEIT has good internal reliability (Mayer, Salovey, & Caruso, 2004) and satisfactory convergent, discriminant, and predictive validity (Day & Carroll, 2004; McEnrue & Groves, 2006). The MSCEIT is comprised of 141 items which conceptually make up four first-order factors (i.e., Branches), two second-order factors (i.e., Areas), and one-third order factor (i.e., Overall emotional intelligence), all derived from eight task scores. Although some subtasks of the MSCIET appear to have low internal consistencies (G. Matthews, Roberts, & Zeidner, 2004), they were not designed to be used individually (Mayer et al., 2004). For the present report, area scores for perceptual and strategic knowledge were derived using the general consensus scoring criteria (Mayer et al., 2002). The 'perceptual knowledge' area reflects the ability to perceive, experience and recognize emotions in the self and the environment, whereas strategic knowledge scores reflect knowledge regarding how to best regulate and manage emotions in order to attain goals In the present sample α =.72 and α =.63 for the perceptual and strategic scales respectively.

Inflammation: Blood samples were collected in EDTA coated vacutainers, converted to plasma, and stored at -80°C. A local laboratory tested plasma for CRP concentrations, and a high sensitivity bead-based multiplex assay (BioLegend, San Diego, CA, USA) was used to test for concentrations of IL-4, IL-6, IL-8, TNF and IFN-γ. Samples were run in duplicate, and average Median Fluorescent Intensity (MFI) scores are reported. The standard curve coefficient variation's (CV's) ranged from (0.43-2%), and mean participant CV's were 4.0%, 4.5%, 8.7%, 6.3%, 6.7% and for IL-4, IL-6, IL-8, IFNγ, and TNF respectively. Samples identified as having a CV over 20% were excluded, as were outliers, identified using the outlier labelling rule; $F_U + 1.5(F_U — F_L)$ (e.g. Hoaglin & Iglewicz, 1987).

Bio-behavioral confounds

Body Mass Index (BMI) Height and weight were measured prior to the blood draw and BMI was calculated as weight (kilograms) divided by height (centimetres) squared (see Table 8.1).

Diagnosis counts; participants indicated (yes/no) whether they had a dietary deficiency, a bowel condition, compromised immune function, psychological diagnosis, cancer, or other serious health condition. Conditions were summed to generate a diagnosis count (see Table 8.1).

Progesterone: As progesterone levels influence CRP (Wander, Brindle, & O'Connor, 2008), four items asked about oral contraceptive use and pregnancy. Participants indicated whether they were pregnant (yes/no), the form of contraception they were using (if any), and the start date of their most recent period. Participants were then allocated a score on a 3 point scale according to their estimated level of progesterone. Those not on hormonal contraception were given a score of 1 or 2 depending on whether they were in the follicular or luteal phase respectively, whereas those on hormonal contraception (or pregnant) scored 3. Approximately 50% of participants were using hormonal contraception and no participants were pregnant (see Table 8.1).

Physical Activity: Activity levels were assessed using the self-reported component of the University of Houston Non-Exercise Test for Predicting Maximal Oxygen Consumption (VO^2max). This algorithm combines self-reported activity (derived from the NASA/JSC physical activity scale (PA-R) (Ross & Jackson, 1990)) with gender, age and body composition, to generate an estimate of VO_{2max} that is appropriate for over 95% of the population and comparable to established submaximal treadmill prediction models (A. S. Jackson et al., 1990). Participants reported their physical activity over the past month on a scale from 0 "Did not participate in programmed recreation, sport or heavy physical activity. Avoided walking or exertion, e.g., always used the elevator, drove whenever possible instead of walking", to 7 "Participated regularly in heavy physical exercise such as running or jogging… or spent over 3 hours per week in comparable physical activity". Scores of 0-1 represent very low physical activity, scores of 2-3 represent moderate physical activity, and scores of 4-7 represent regular, heavy physical exercise (see Table 8.1).

8.5.4 Analytic Strategy

Univariate relationships between study variables were assessed with Pearson's correlations. Following this, linear regressions tested whether expressive skill and knowledge variables predicted self-reported depressive symptoms, trait anxiety, physical symptoms and self-rated health, as well as immunoregulatory molecules; IL-4, IL-6, IL-8, CRP, TNF and IFN-γ, while controlling for a range of demographic and biobehavioral confounds. Given the exploratory nature of this work, coupled with the limitations imposed by our sample size, forward entry was used to enable the algorithm to select only those covariates that best improved model fit (p in = .10, p out = .10). Likewise, given the absence of prior work offering theoretical justification for selecting which individual skill variables were most likely to predict outcomes, the full range of expressive skill and knowledge variables, along with overall skill scores were also forward entered, thus allowing significant (or near significant) predictors to enter the model (p in = .10, p out = .10).

8.6 Results

8.6.1 Zero-order correlations

Skill in expressing disgust, happiness and sadness, as well as overall expressive skill and strategic knowledge were all associated with fewer depressive symptoms (see Table 8.2). Similarly, trait anxiety was negatively correlated with disgust, happiness, and sadness skill as well as with fear and total expressive skill, but not knowledge variables. Skill in expressing disgust, happiness, fear, and overall skill were associated with better self-rated health, whereas skill in expressing happiness, sadness, fear and overall skill, as well as lower strategic knowledge were negatively associated with symptom reports (see Table 8.2). In terms of immunoregulatory molecules, skill in expressing contempt was associated with higher IL-6 and higher CRP, whereas greater disgust and overall skill were associated with higher IL-8. Conversely, skill in expressing happiness was associated with lower TNF, and perceptual knowledge was

Table 8.2: Zero order correlations between known covariates, expressive skill, emotional intelligence and both self-reported and biological outcome variables

	Depressive symptoms	Trait anxiety	Self-rated health	Symptom reports	IL-4	IL-6	IL-8	TNF	IFN-y	CRP
Covariates										
Age	-.06	-.00	.08	-.07	.18	.28*	.11	.21ᵗ	.07	.15
Ethnicity [a]	.25*	.16	-.08	.11	-.04	-.18	.22ᵗ	.07	.01	-.08
BMI	-.01	-.02	-.12	-.04	.00	.11	-.12	-.04	-.03	.43**
Progesterone	.09	.13	.08	.18	.00	.01	-.27*	-.04	.07	.38**
Activity	-.26*	-.17	.46**	-.15	.13	-.07ᵗ	-.02	.20ᵗ	.21ᵗ	-.05
Diagnoses	.35**	.40**	-.38**	.56**	-.08	.16	-.14	.05	.05	.14
Income	-.12	-.11	-.06	-.06	.18	.12	.15	.02	.30*	-.06
Skill										
Anger	-.17	-.13	.13	-.13	.12	.14	.17	.12	.07	.08ᵗ
Contempt	-.05	.04	.10	-.08	.08	.24*	.19	-.04	.08	.24*
Disgust	-.26*	-.27*	.26*	-.18	.05	.10	.27*	-.09	.02	.13
Happy	-.32**	-.25*	.31**	-.30**	-.02	-.02	.17	-.34**	.00	.14
Sad	-.23*	-.26*	.10	-.30**	-.06	.00	.17	-.08	.01	.04
Embarrassed	-.14	-.14	.06	-.18	.13	.08	.13	.13	.15	.12
Guilt	-.13	-.03	.14	-.17	.06	.04	.06	.04	.14	.13
Interest	-.20ᵗ	-.19ᵗ	.10	-.07	.00	-.09	.06	-.16	.07	-.05
Surprise	-.21ᵗ	-.17	.10	-.11	.10	.03	.16	.08	.19	.15
Fear	-.19ᵗ	-.23*	.27*	-.27*	.10	.09	.03	.15	-.07	.15
Total	-.31**	-.27*	.25*	-.27*	.10	.10	.24*	-.01	.12	.18
Knowledge										
Perceptual	-.16	-.01	.08	-.04	-.16	.12	-.29*	.03	-.04	.12
Strategic	-.38**	-.11	.10	-.25*	-.04	.08	-.09	.00	.11	.14

** p <.01, *p<.05, ᵗ p <.10

[a] White = 0, Not-white = 1

associated with lower IL-8 (see Table 8.2).

8.6.2 Multivariate predictors of outcomes

Multivariate predictors of depressive symptoms (standardized betas reported)

Forward entry of covariates produced a significant model (F (1, 78) = 10.72 p < .01), with diagnosis counts entering first and explaining 12% variance in depressive symptoms; higher diagnosis counts predicted more depressive symptoms (β = .35, p < .01). Ethnicity then entered the model (F (2, 77) = 9.93, p < .01), and explained a further 8% variance, ($F\Delta$ (1, 77) = 8.15, p < .01); being 'not white' was associated with more depressive symptoms (β = .29, p < .01). Forward entry of EC variables also produced a significant model (F (3, 76) = 14.32, p < .01), with strategic knowledge entering the model and explaining a further 16% variance in depressive symptoms ($F\Delta$ (1, 76) = 18.57, p < .01); greater knowledge predicted fewer depressive symptoms (β = -.40, p < .05). Overall expressive skill then entered the model in the final step (F (4, 75) = 12.28, p < .01), explaining an additional 4% variance ($F\Delta$ (1, 75) = 4.30, p < .05), with greater skill predicting fewer symptoms (β = -.20, p < .05) (see Table 8.3).

Multivariate predictors of trait anxiety (standardized betas reported)

Forward entry of covariates produced a significant model (F (1, 78) = 13.40 p < .01), with diagnosis counts entering first and explaining 16% variance in trait anxiety; higher diagnosis counts predicted greater anxiety (β = .40, p < .01). Ethnicity then entered the model (F (2, 77) = 9.49, p < .01), and explained a further 4% variance, ($F\Delta$ (1, 77) = 4.03, p < .05); being 'not white' was associated with greater anxiety (β = .21, p < .05). Forward entry of EC variables also produced a significant model (F (3, 76) = 8.64, p < .01), with skill in expressing disgust entering and explaining a further 6%

Table 8.3: Results showing the final step for four forward entry linear regressions, showing how expressive skill and emotional knowledge predict self-reported outcomes while controlling for known demographic and bio-behavioral confounds

	Depressive Symptoms				Trait Anxiety				Self-rated health				Symptom Reports			
	Beta	SE	*B*	sr^2	Beta	SE	*B*	sr^2	Beta	SE	*B*	sr^2	Beta	SE	*B*	sr^2
Covariates																
Age	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ethnicity [a]	3.13	1.86	.16ƚ	.02	-	-	-	-	-	-	-	-	-	-	-	-
BMI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Progesterone	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Activity	-	-	-	-	-	-	-	-	0.15	0.04	.37**	.13	-	-	-	-
Diagnoses	3.66	0.81	.41**	.16	4.67	1.05	.44**	.19	-0.29	0.09	-.29**	.08	0.16	0.02	.59**	0.34
Skill																
Angry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contempt	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Disgust	-	-	-	-	-0.61	0.27	-.23*	.05	-	-	-	-	-	-	-	-
Happy	-	-	-	-	-	-	-	-	0.06	0.03	.22*	.05	-	-	-	-
Sad	-	-	-	-	-	-	-	-	-	-	-	-	-0.02	0.01	-.23*	0.05
Embarrassed	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guilty	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surprise	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	-0.87	0.42	-0.20*	0.03	-	-	-	-	-	-	-	-	-	-	-	-
Knowledge																
Perceptual	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Strategic	-0.40	0.10	-0.39**	0.14	-0.23	0.12	-0.19ƚ	0.03					-0.01	0.00	-0.31**	0.09

** p <.01, *p <.05, ƚ p <.10, sr^2 = squared part correlations

[a] White = 0, Not-white = 1

variance in anxiety scores (*FΔ* (1, 76) = 5.76, $p < .05$); greater disgust skill predicted lower anxiety (β = -.25, $p < .05$). Strategic knowledge then entered the model in the final step (*F* (4, 75) = 7.55, $p < .01$), explaining an additional 3% variance, however the change in *F* was marginal (*FΔ* (1, 75) = 3.45, $p = .07$), with greater strategic knowledge marginally predicting lower anxiety (β = -.19, $p = .07$) (see Table 8.3).

Multivariate predictors of self-rated health (standardized betas reported)

Forward entry of covariates produced a significant model (*F* (1, 78) = 20.50 $p < .01$), with activity level entering first and explaining 20% variance in self-rated health; greater activity was associated with higher self-rated health (β = .46, $p < .01$). Diagnosis counts then entered (*F* (2, 77) = 16.72, $p < .01$), and explained a further 10% variance, (*FΔ* (1, 77) = 10.46, $p < .01$); more diagnoses predicted lower self-rated health (β = -.31, $p < .01$). Finally, forward entry of EC variables produced a significant model (*F* (3, 76) = 13.57, $p < .01$), with skill in expressing happiness entering and explaining a further 5% variance in self-rated health (*FΔ* (1, 76) = 5.37, $p < .05$); greater skill predicted better self-rated health (β = .22, $p < .05$) (see Table 8.3).

Multivariate predictors of symptom reports (standardized betas reported)

Forward entry of covariates produced a significant model (*F* (1, 78) = 35.03, $p < .01$), with diagnosis counts entering the model first and explaining 31% variance in symptom reports; higher counts were associated with more symptoms (β = .56, $p < .01$). Ethnicity then entered the model (*F* (2, 77) = 19.73, $p < .01$), and marginally explained a further 3% variance, (*FΔ* (1, 77) = 3.37, $p = .07$); being not white was marginally associated with more symptoms (β = -.31, $p = .07$). Forward entry of EC variables also produced a significant model (*F* (3, 76) = 19.31, $p < .01$), with strategic knowledge explaining a further 9% variance in symptom reporting (*FΔ* (1, 76) = 12.54, $p < .01$); greater knowledge predicted fewer symptoms (β = -.31, $p < .01$). Finally, skill in expressing sadness entered the model (*F*

(4, 75) = 17.75, $p < .01$), explaining an additional 5% variance ($F\Delta$ (1, 75) = 7.84, $p < .01$). Greater skill in expressing sadness predicted fewer symptoms (β = -.24, $p < .01$) (see Table 8.3).

Multivariate predictors of IL-4 (standardized betas reported)

No variables entered the model.

Multivariate predictors of IL-6 (standardized betas reported)

Forward entry of covariates produced a significant model (F (1, 71) = 6.12, $p < .05$), with age entering the model and explaining 8% variance in IL-6; greater age was associated with higher IL-6 (β = .28, $p < .05$). Forward entry of EC variables produced a marginally significant model (F (2, 70) = 4.79, $p = .08$), with contempt explaining a further 4% variance in IL-6 ($F\Delta$ (1, 70) = 3.25, $p = .08$), with greater skill marginally predicting higher IL-6 (β = .20, $p = .08$) (see Table 8.4).

Multivariate predictors of IL-8 (standardized betas reported)

Forward entry of covariates produced a significant model (F (1, 63) = 4.85, $p < .05$), with progesterone entering the model and explaining 7% variance in IL-8; higher progesterone was associated with lower IL-8 (β = -.27, $p < .05$). Forward entry of EC variables produced a marginally significant model (F (2, 62) = 5.55, $p = .05$), with skill in expressing disgust explaining a further 8% variance in IL-8 ($F\Delta$ (1, 62) = 5.87, $p < .05$); greater skill expressing disgust predicted higher IL-8 (β = .28, $p < .05$). Perceptual knowledge then entered the model in the final step (F (3, 61) = 6.29, $p < .01$), explaining a further 8% variance in IL-8 ($F\Delta$ (1, 61) = 6.74, $p < .05$); greater knowledge predicted lower IL-8 (β = -.29, $p < .05$) (see Table 8.4).

Multivariate predictors of TNF (standardized betas reported)

Table 8.4: Results showing the final step for five forward entry linear regressions, showing how expressive skill and emotional knowledge predict immune parameters while controlling for known demographic and bio-behavioral confounds. Note, IL-4 is not included

	IL-6				IL-8				TNF				IFN-y				CRP			
	Beta	SE	*B*	sr^2	Beta	SE	*B*	sr^2	Beta	SE	*B*	sr^2	Beta	SE	*B*	sr^2	Beta	SE	*B*	sr^2
Covariates																				
Age	3.80	1.69	.26*	.06	-	-	-	-	1.54	0.65	.25*	.06	-	-	-	-	-	-	-	-
Ethnicity [a]	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Income	-	-	-	-	-	-	-	-	-	-	-	-	8.06	2.69	.34*	.11	-	-	-	-
BMI	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.11	0.03	.39**	.00
Progesterone	-	-	-	-	-49.03	21.29	-.26*	.07	-	-	-	-	-	-	-	-	0.43	0.11	.38**	.00
Activity	-	-	-	-	-	-	-	-	3.33	1.23	.29**	.08	5.37	2.67	.22*	.05	-	-	-	-
Diagnoses	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Skill																				
Angry	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Contempt	5.11	2.83	.20ŧ	.04	-	-	-	-	-	-	-	-	-	-	-	-	0.07	0.03	.20*	.05
Disgust	-	-	-	-	12.19	4.47	.31**	.05	-	-	-	-	-	-	-	-	-	-	-	-
Happy	-	-	-	-	-	-	-	-	-3.27	0.85	-.42**	.17	-	-	-	-	-	-	-	-
Embarrassed	-	-	-	-	-	-	-	-	2.74	1.42	.21ŧ	.04	6.08	3.14	.22ŧ	.04	-	-	-	-
Sad	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Guilty	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Interest	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Surprise	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Knowledge																				
Perceptual	-	-	-	-	-2.73	1.05	-0.29*	.10	-	-	-	-	-	-	-	-	-	-	-	-
Strategic	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

** p <.01, *p <.05, ŧ p <.10, sr^2 = squared part correlations

[a] White = 0, Not-white = 1

Forward entry of covariates produced a marginally significant model (F (1, 68) = 3.25, p = .08), with age explaining 3% variance in TNF; higher age was marginally associated with higher TNF (β = .21, p = .08). Activity level then entered the model (F (2, 67) = 3.43, p < .05), and marginally explained a further 9% variance in TNF ($F\Delta$ (1, 67) = 3.50, p = .07), with greater activity predicting higher TNF (β = .22, p = .07). Expressive skill for happiness then entered the model (F (3, 66) = 6.86, p < .01), explaining a further 15% variance in TNF ($F\Delta$ (1, 66) = 12.54, p < .01), with happy skill predicting lower TNF (β = -.39, p < .01). Following this skill for embarrassment entered the model (F (4, 65) = 6.30, p < .01), with skill in expressing embarrassment marginally explaining 4% variance in TNF ($F\Delta$ (1, 65) = 3.75, p = .06); greater skill was marginally associated with higher TNF (β = .21, p = .06).

Multivariate predictors of IFN-γ (standardized betas reported)

Forward entry of covariates produced a significant model (F (1, 69) = 6.79, p < .05), with income explaining 9% variance in IFN-γ; greater income was associated with higher IFN-γ (β = .30, p < .05). Activity level then entered the model (F (2, 68) = 5.23, p < .01), marginally explaining a further 4% variance in IFN-γ ($F\Delta$ (1, 68) = 3.43, p = .07), with greater activity marginally predicting higher IFN-γ (β = .21, p = .07). Expressive skill for embarrassment then entered the model (F (3, 67) = 4.87, p < .05), marginally explaining a further 5% variance in IFN-γ ($F\Delta$ (1, 67) = 3.75, p = .06), with skill for embarrassment marginally predicting higher IFN-γ (β = .22, p = .06) (see Table 8.4).

Multivariate predictors of CRP (standardized betas reported)

Forward entry of covariates produced a significant model (F (1, 70) = 15.78, p < .01), with BMI explaining 18% variance in CRP; higher BMI was associated with higher CRP (β = .43, p < .01). Progesterone then entered the model (F (2, 69) = 16.52, p < .01), explaining a further 14% variance in CRP ($F\Delta$ (1, 69) = 14.27, p < .01), with higher progesterone predicting higher CRP (β = .37, p < .01). Expressive skill for contempt then entered the model (F (3, 68) = 12.81, p < .01), explaining a further 4% variance in CRP *($F\Delta$* (1, 68) = 3.98, p = .05), with skill for contempt predicting higher CRP (β = .20, p = .05) (see Table 8.4).

8.7 Discussion

The present report examined whether performance-based assessments of expressive skill and emotional knowledge predicted self-reported depressive symptoms, anxiety and physical health constructs, and whether links would extend to a range of immunoregulatory molecules. Given evidence that trait ECs may influence health via patterns of pro-inflammatory cytokines, we predicted that individuals with greater expressive skill and emotional knowledge would report better psychological and physical wellbeing and display healthier concentrations of immunoregulatory molecules. These hypotheses were partially confirmed; specifically, greater expressive skill was associated with fewer depressive symptoms, lower anxiety, better self-rated health, and fewer reported physical symptoms. However, although skill scores were also associated with several pro-inflammatory cytokines and CRP, findings were more complicated; skill in expressing happiness predicted lower, and skill in expressing disgust, contempt, and embarrassment predicted higher (or marginally higher) concentrations of immunoregulatory molecules. Below, several possible interpretations and potential mechanisms are suggested, and future directions are outlined.

8.7.1 Expressive regulatory skill, depressive symptoms and anxiety

The first major contribution of this report lies in showing that objective assessments of expressive skill predict fewer depressive symptoms and lower trait anxiety. Although prior work has documented deficits in expressivity among depressed groups (Gaebel & Wölwer, 1992; Trémeau et al., 2005) and trait positive expressivity has been linked to lower rates of depression (Davidson et al., 2010), the present report represents the first evidence that the *ability* to facially express emotions is associated with depressive symptoms and trait anxiety in a community sample.

One possible interpretation is that among those with low skill, the signal function of emotions may become unclear or lost, thus failing to elicit the desired or appropriate response in others. For example, sad expressions signal the need for social support, whereas expressing anger communicates that a goal has been blocked (Blair, 2003; Keltner & Ekman, 2000; Keltner & Haidt, 1999). Deficits in expressive skill may limit available social resources and hinder goal attainment, potentially increasing risk of depression. The finding that overall skill was most predictive, coupled with correlations linking skill for both positive *and negative* expressions to better outcomes (see Table 8.2) suggests that rather than being specific to positive expressions, the ability to flexibly express both positive and negative emotions is most adaptive in terms of psychological wellbeing (Bonanno et al., 2004). Evidence that strategic knowledge, responsible for higher order, goal directed emotion regulation and problem solving, was also associated with fewer depressive symptoms and lower trait anxiety lends further support to this possibility and future work testing whether improving strategic knowledge leads to better outcomes is warranted.

8.7.2 Expressive regulatory skill and self-reported health

Second, the current report extends prior work by demonstrating that the links between trait ECs and self-reported physical health are also apparent among objectively-assessed expressive skills. Symptom reports are central to both health behaviours and general wellbeing (Frostholm et al., 2005; Kroenke et al., 1994), and self-rated health reports predict mortality independently of known medical, behavioural, and psychosocial risks (Idler & Benyamini, 1997). As such, evidence that the ability to facially express emotions predicts these outcomes, even when controlling for diagnosis counts, suggests that expressive skills may have important links with health and wellbeing that warrant further investigation.

In terms of mechanisms, being able to express emotions in the moment necessitates the coordination of multiple cognitive, neural, and physiological systems. In theory, a more adaptive and flexible system should be better able to efficiently manage this task (Lane et al., 2009; Thayer & Lane, 2000). Likewise, expressive capacities may decline when a person is stressed or his/her resources become more limited (Baumeister, Vohs, & Tice, 2007; Muraven & Baumeister, 2000), such as when experiencing physical symptoms or when confronted with a health threat.

8.7.3 Expressive regulatory skill and immunoregulatory molecules

Although prior work has shown that trait ECs predict inflammation and disease risk (Appleton, Buka, Loucks, Gilman, et al., 2013; Jaremka et al., 2013; Kendall-Tackett, 2010), the present report represents early evidence that objectively-assessed expressive skills may also have links with immunoregulatory molecules, specifically pro-inflammatory cytokines IL-8, TNF, and the acute phase protein CRP. However, rather than predicting *lower* concentrations of biomarkers, analyses indicated that skill in expressing disgust predicted higher IL-8, contempt skill predicted higher CRP and, marginally, predicted higher IL-6, and skill for embarrassment marginally predicted higher TNF and IFN-γ. In contrast, the ability to express happiness was associated with lower TNF, and perceptual knowledge predicted lower IL-8.

These findings suggest that skill in expressing positive versus negative emotions may have divergent links to immunoregulatory molecules, whereby emotions associated with hostility or shame (contempt, disgust and embarrassment) are predicting higher concentrations, whereas expressive skill for positive emotions appears to be associated with lower concentrations of pro-inflammatory cytokines. Given that numerous studies have documented links between pro-inflammatory cytokines and both hostility and shame (Dickerson, Gruenewald, & Kemeny, 2004; Kendall-Tackett, 2010; Rohleder, Chen, Wolf, & Miller, 2008), it is possible that individuals exhibit greater skill in expressing the specific emotions that they most frequently experience and signal. For example, an individual who frequently expresses hostility may become increasingly skilled at signalling hostile emotions (or vice-versa). Over time this underlying hostility may influence the HPA axis and peripheral pro-inflammatory activity (Demarble et al., 2014; Ranjit et al., 2007), potentially increasing disease risk (Black & Garbutt, 2002; Danesh et al., 2004). However, although this pattern of responding is theoretically plausible, links between expressive skill and immunoregulatory molecules did not reveal a systematic pattern, and, given the large number of immunoregulatory molecules assessed, Type 1 errors may underpin at least some of these findings.

An alternative possibility is that these results represent the first part of a curvilinear relationship, whereby within a young, community sample, moderate immunoregulatory responding when facing a physical challenge (blood draw) may indicate a more responsive system. The skill task required a high degree of reactivity (i.e., high speed responding) and persons may "react" in varying degrees to external challenges, including both blood draws and the skill task, in particular ways across the board. Rather than picking up on underlying differences in physical health and disease risk, these data may thus be capturing flexible responding; future work in samples with greater variation in inflammatory profiles could test this possibility.

8.8 Limitations and future directions

Despite advantages, these data are not without limitations. Findings from a homogenous sample of young, healthy females cannot be generalised to older samples, men, or clinical groups. Furthermore, causality remains unclear. Although expressive skill may be a protective factor, buffering the effects of daily stressors, reducing the risk of depression and anxiety, and improving reported health, it is equally possible that those experiencing physiological or psychological symptoms are less able to express emotions due to system fatigue, motivation, or attentional issues. Future work in more diverse groups, together with longitudinal and experimental studies should lead to greater understanding of this relationship.

Another limitation inherent in cross sectional designs is the influence of unknown and un-measured third variables. For example, social environments, state anxiety, and perceived stress may be related to both expressive skill and to immune parameters. Data regarding these variables were not collected. In a related vein, data regarding medication use were not available. Antidepressants and anti-hypertensive medications may influence inflammatory markers (O'Connor et al., 2009), however controlling for diagnosis counts may have gone some way towards accounting for effects of this kind. Additionally, although they were reliable, coders were not trained using a specific system. Expressions were scored based on global impressions, and although this appears sufficient to demonstrate a 'proof of principle', future work should consider using coding systems such as the Facial Action Coding System (FACS) (Ekman & Rosenberg, 1997) or automated facial software. In addition, given the exploratory nature of this work, we looked at a large number of predictor and outcome variables, and multiple comparisons are likely to have increased the risk of Type 1 errors. Future work can use this study to help guide more specific, hypothesis driven work, that looks at a broader range of physical and psychological outcomes (such as state anxiety and perceived stress), to better understand these links.

Overall, evidence that objective, performance measures of expressive skill and knowledge predict outcomes may illuminate interventional pathways that are absent from trait-based approaches. However, future work clarifying the direction of the relationship is needed before specific pathways can be considered. Studies within applied settings, for example, testing whether expressive skill improves following the administration of anti-depressive treatments, may offer insight into the temporal nature of these links. Additionally, measuring the ability to express emotions in response to stimuli might be a useful and valid extension of this approach. More broadly, evidence that both emotional knowledge and expressive skills were associated with outcomes suggests that training these abilities may be of benefit, particularly (given the links with depressive and physical symptoms) among persons at risk of high healthcare utilization and psychosocial morbidity.

Limitations withstanding, it is increasingly apparent that ECs predict health and mortality, and the present report presents initial evidence that an objective test of expressive skill predicts self-rated health, physical symptoms, depressive symptoms and anxiety, as well as showing links with several immunoregulatory molecules that are relevant to health. Performance-based skill and knowledge metrics bypass the pitfalls of self-report and as such have numerous conceptual and methodological advantages over self-reported measures. Evidence of links to a diverse range of outcomes suggests that future work-based on this paradigm is warranted, including whether this approach can be considered a proxy for real world expressive skill.

Chapter 9 : Do expressive skills predict clinically relevant health outcomes?

9.1 Preface

In addition to links with self-reported psychological and physical health outcomes, the previous chapter demonstrated that the ability to accurately signal specific emotions in the face is also associated with several immunoregulatory molecules. Despite being preliminary and in need of replication, these findings, coupled with earlier evidence that expressive skills predict HRV (Chapters 6 and 7) suggest that links between expressive skill and outcomes are not limited to self-reported wellbeing, but can be extended to biological parameters.

However, although HRV (Dekker et al., 2000; Thayer et al., 2012) and inflammation (Hansson 2005; Willeit et al., 2016) are frequently treated as health-proxies, and predict health outcomes, they are not actually health outcomes in their own right. Therefore, despite showing that expressive skills are related to physiological and biological parameters (that may be indicative of health status), these findings do not provide direct evidence of links between regulatory skills and physical health *outcomes*. In addressing this limitation, the current chapter provides a first empirical test of whether the ability to signal specific emotions is associated with objectively assessed and clinically relevant indices of physical health.

Although various operationalisations of emotion regulation have been associated with a range of health outcomes, among the most consistent findings are those linking emotion regulation with cardiovascular health (see Chapter 2). Since early work documenting links between the Type A personality and poorer cardiac outcomes (M. Friedman & Rosenman, 1959), researchers have repeatedly found links between emotion regulation and CVD risk, with studies reporting that better emotion-regulation predicts lower scores on risk metrics (Appleton, Buka, Loucks, Rimm, et al., 2013; Appleton et al., 2014; Kubzansky et al., 2011; Potijk et al., 2016). As noted however, work thus far has been based on self-reported ability, psychologist reports, or trait expressivity, and it is unclear whether skill-based assessments of the ability to regulate expressivity will also be associated with cardiac outcomes.

Despite the absence of prior studies, there is good reason to expect that the operationalisations of expressive regulatory skill developed in this thesis should predict better cardiac health. For one, previous chapters have shown that expressive skills predict symptom reporting and perceived health, both of which are associated with morbidity and mortality (McGee, Liao, Cao, & Cooper, 1999). Equally, the fact that skill-based operationalisations predict both HRV and inflammation which are, in turn, associated with cardiac outcomes (Dekker et al., 2000; Hansson 2005; Thayer et al., 2012; Willeit et al., 2016), suggests that links between expressive skills and cardiac risk are possible. Therefore, in extending prior work linking expressive regulatory skills with health proxies, the present chapter examines whether the ability to express specific emotions is associated with projected CVD risk.

Although this thesis has not primarily been concerned with considering which specific types of expressive regulatory skills best predict precise health outcomes, links at this level of specificity are possible. As is discussed in Chapter 10, determining the optimal operationalisations of expressive regulatory skill for predicting different outcomes will be an important area of future study. In preliminarily considering which specific skill-based operationalisations should be expected to correspond to CVD risk, skill in expressing positive emotion is a promising candidate.

It has been proposed that the ability to signal positive emotion (perhaps particularly in the face of adversity) may lead to better outcomes by facilitating recovery from stressors and 'undoing' the physiological and emotional consequences of NA (Bonanno & Keltner, 1997; Fredrickson, 1998, 2013; Fredrickson & Levenson, 1998; Papa & Bonanno, 2008). In addition to these intrapersonal effects, the expression of positive emotion may also lead to better outcomes by increasing social resources (Papa & Bonanno, 2008; Sel, Calvo-Merino, Tuettenberg, & Forster, 2015), which then buffer against the impact of daily stressors (Cacioppo & Cacioppo, 2014; Kok et al., 2013).

Evidence from both epidemiological and laboratory based studies is consistent with this position. For example, the act of smiling (regardless of underlying emotion) has been shown to speed cardiovascular recovery following exposure to a stressor (Kraft & Pressman, 2012), and the general tendency to express positive emotion is associated with lower CVD risk (Davidson et al., 2010; Hayashi et al., 2016). Of particular relevance to the current methodology, the intensity of smiles in photographs prospectively predicts psychosocial wellbeing, marital satisfaction (Harker & Keltner, 2001) and mortality (Abel & Kruger, 2010). Such findings may indicate that the *ability* to smile, regardless of underlying emotion, is associated with physical health and wellbeing. However, because this possibility has not yet been directly tested, the current chapter presents an investigation of whether objectively-assessed skill in signalling positive emotion is associated with projected CVD risk.

In summary, to test whether the links between expressive skills and both biological and physiological parameters can be extended to clinically relevant health outcomes, and to investigate whether the *ability* to signal positive emotion is associated with physical health outcomes, the current chapter presents an empirical report testing whether the objectively assessed ability to signal positive emotion is associated with three measures of projected CVD risk.

9.2 Citation

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9.3 Abstract

Positive emotion is associated with lower cardiovascular disease (CVD) risk, yet some mechanisms remain unclear. One potential pathway is via emotional competencies/skills. The present study tests whether the ability to facially express positive emotion is associated with CVD risk scores, while controlling for potential confounds and testing for sex moderation. Eighty-two men and women underwent blood draws before completing self-report assessments and a performance test of expressive skill. Positive expressions were scored for degree of 'happiness' using expression coding software. CVD risk scores were calculated using established algorithms based on biological, demographic, and behavioral risk factors. Linear regressions revealed a main effect for skill, with skill in expressing positive emotion associated with lower CVD risk scores. Analyses also revealed a sex-by-skill interaction whereby links between expressive skill and CVD risk scores were stronger among men. Objective tests of expressive skill have methodological advantages, appear to have links to physical health, and offer a novel avenue for research and intervention.

9.4 Introduction

Positive emotionality appears to predict better health and lower future disease risk (Chida & Steptoe, 2008; Howell, Kern, & Lyubomirsky, 2007; Pressman & Cohen, 2005). Although work has largely focused on positive emotional experience, evidence suggests that the expression of positive emotion may also have links with health, including reduced cardiovascular disease (CVD) risk (Davidson et al., 2010; Hayashi et al., 2016). However, whether individual differences in the ability to express positive emotions are also associated with cardiac outcomes remains unknown. Therefore, the present study tests whether objective measures of the ability to deliberately express positive emotion predicts CVD risk scores.

Although facial expressions can be spontaneous signals of internal experience, expressions are also intentionally adjusted in a manner that regulates autonomic and affective processes, and influences social interactions (Kraft & Pressman, 2012; Owren & Bachorowski, 2001; Soussignan, 2002). Greater skill in deliberately expressing emotions may thus confer an adaptive advantage (Consedine, Magai, & Bonanno, 2002) and, although numerous expressions might predict outcomes, evidence of links between positive expressivity and lower cardiac risk (Davidson et al., 2010), suggest that an initial focus on the ability to express positive emotion is warranted.

Skill in expressing positive emotions may predict cardiac risk via several pathways. First, positive expressions are thought to have evolved to signal a willingness to interact and co-operate (Owren & Bachorowski, 2001), potentially increasing social resources and/or reducing the risk of loneliness and isolation, both established CVD risk factors (Valtorta, Kanaan, Gilbody, Ronzi, & Hanratty, 2016). Second, the ability to deliberately express positive emotion may reflect differences in general regulatory capacities (Soussignan, 2002), which in turn predict lower cardiac risk (Potijk et al., 2016). Finally, deliberate smiles may reduce risk via directly lowering physiological arousal (e.g. Fredrickson, 2013; Kraft & Pressman, 2012; Tuck, Grant, Sollers III, et al., 2016).

Although links between expressive skill and projected CVD risk have not been systematically examined, the ability to signal positive emotion has been associated with better perceived health, lower concentrations of inflammatory markers (Tuck, Grant, Jackson, et al., 2016), and higher heart rate variability (Tuck, Grant, Sollers III, et al., 2016). Other work has shown that smile intensity prospectively predicts personality, marital stability, and mortality (Abel & Kruger, 2010; Harker & Keltner, 2001) and, although such data are typically interpreted as reflecting differences in trait positive affect (PA), differences in smile intensity may reflect differences in expressive capabilities. However, although expressive skill predicts more adaptive patterns of physical and emotional responding (Tuck, Grant, Jackson, et al., 2016), it is unknown whether the ability to signal positive emotion will also predict clinically relevant health metrics.

Consequently, the present report assessed whether the ability to express positive emotion was associated with CVD risk scores. In contrast to cardiac morbidity and mortality, CVD risk scores use validated algorithms to predict risk of future cardiac events in non-clinical samples, using traditional biological, demographic and behavioral risk factors. Such measures reliably predict future incidence of cardiac outcomes, including coronary death, myocardial infarction, and heart failure (D'Agostino et al., 2008). Although trait emotion regulation has been associated with estimates of projected CVD risk (Appleton & Kubzansky, 2014), the possibility that expressive regulatory skills will also be associated with cardiac risk scores has not been tested.

Nonetheless, our expectation was that greater ability would be associated with a lower projected CVD risk. Furthermore, given evidence that links between psychosocial parameters and disease risk may be more apparent among men (Yang, McClintock, Kozloski, & Li, 2013), and to clarify whether potential links can be attributed to underlying emotional and/or social factors, the current study investigated whether links between positive expressive skill (PES) and three CVD risk scores were comparable across men and women, and while controlling for trait PA, depressive symptoms, and loneliness.

9.5 Methods

9.5.1 Participants

An *a-priori* power analysis using G-Power software was run based on α = .05 and power = 80% (Faul, Erdfelder, Buchner, & Lang, 2009). Although the novelty of the predictor variables meant that there was little empirical guidance regarding effect sizes, an effect size of R^2 =.15 was previously reported in links between positive expressive skill and the inflammatory marker interferon gamma (IFN-γ) (Tuck, Grant, Jackson, et al., 2016). Thus, power analyses using a slightly more conservative range of effect sizes (R^2 = 0.10 – 0.15) indicated that a sample size of N = 67 – 103 should provide 80% power.

Ninety-eight participants were recruited between November 2015 and January 2016 for a cross sectional study titled 'Emotions and Health' in Auckland, New Zealand, via university and hospital staff mailing lists and word of mouth. Advertisements invited participants aged 30 and over to "take part in a study examining how social and emotional factors are related to health outcomes such as cardiovascular disease risk." Photographs of 15 participants were not of sufficient quality to be analyzed, and venepuncture could not be completed for one participant, resulting in a final sample of 82 participants with complete data (see Table 1).

9.5.2 Procedure

Following informed consent, participants completed online measures of demographics, health, trait emotion, and emotional intelligence (EI) before attending a laboratory session at a clinical research centre. Upon arrival, height and weight were measured, followed by a blood draw (details below), before participants completed assessments of social skills. Participants were then fitted with a Polar watch heart rate monitor and chest strap (model RS800CX), before completing an orthostatic heart rate variability (HRV) challenge. Blood pressure was recorded twice (details below) followed by a performance-based assessment of expressive skill. For this, participants were seated at a computer and informed that 10 emotion terms would appear on the monitor. As each term appeared, participants were instructed to pose a genuine and accurate expression of that emotion as rapidly as possible then press the spacebar to record a digital photograph. Resting heart rate (HR) was recorded for a further three minutes. Following this, participants reported how much effort they put into producing target expressions before they were thanked and given a $40 voucher. Analysis of HRV/HR, EI and social skills are also not included in the present report.

9.5.3 Measures

Cardiac Risk Scores:

To account for differences in the relative weighting of CVD risk factors due to nationality (e.g. R. Jackson, 2000), whilst ensuring that findings can be interpreted in the context of prior work (e.g. Appleton, Loucks, et al., 2013; Haynes et al., 1980), three similar but distinct measures of CVD risk were calculated.

Table 9.1 Sample characteristics; stratified by sex with Students t and Chi-square tests of significant differences.

	Men (N=20)			Women (N=62)				
	Count (%)	Mean (SD)	Range	Count (%)	Mean (SD)	Range	Test statistic	*p*
Smoker [1]	1 (5%)	-	-	1 (1.5%)	-	-	-	-
Diabetic [1]	1 (5%)	-	-	1 (1.5%)	-	-	-	-
Taking BP medication [2]	2 (10%)	-	-	8 (13%)	-	-	0.12	0.73
Not-white [2]	6 (30%)	-	-	16 (26%)	-	-	0.14	0.71
Age [3]	-	49.95 (15.50)	31.10 - 75.14	-	51.50 (14.25)	30.05 - 76.39	-0.41	0.68
Cholesterol (mmol/L) [3]	-	5.06 (1.10)	3.30 - 8.10	-	5.34 (1.19)	3.30 - 8.00	-0.96	0.34
HDL cholesterol (mmol/L) [3]	-	1.42 (0.41)	0.90 - 2.50	-	1.75 (0.53)	0.80 - 3.60	-2.61	0.011
HDL ratio [3]	-	3.80 (1.19)	2.30 - 6.20	-	3.29 (1.33)	1.50 - 8.10	1.54	0.13
SBP (mmHg) [3]	-	124.59 (11.18)	107.30 - 144.00	-	118.25 (12.96)	99.00 - 147.00	1.96	0.053
Framingham risk [3,4]	-	-1.49 (2.93)	-4.61 - 2.00	-	-1.76 (2.82)	-4.61 - 2.00	0.37	0.71
NZ risk [3,4]	-	1.36 (1.12)	0.22 - 2.82	-	0.92 (0.83)	0.22 - 2.82	1.87	0.12
ASCVD [3,4]	-	-3.76 (1.90)	-7.05 - -1.64	-	-4.40 (1.71)	-8.08 - -1.64	1.40	0.17
Positive expressive skill [3]	-	0.36 (0.38)	0.00 - 0.98	-	0.45 (0.37)	0.00 - 0.99	-0.95	0.34
Trait positive affect [3]	-	3.36 (0.61)	2.22 - 4.44	-	3.49 (0.43)	2.33 - 4.44	-1.05	0.30
Depressive symptoms [3]	-	11.70 (9.60)	0.00 - 36.00	-	9.89 (7.00)	0.00-31.00	-0.17	0.86
UCLA loneliness[3]	-	18.15 (10.78)	0.00 - 45.00		17.50 (9.12)	2.00 - 41.00	0.27	0.79

1 Test statistic not applicable on counts of 1.
2 Test statistic = chi squared (χ^2)
3 Test statistic = Students *t*-test
4 Risk scores are log transformed and windsorized.

The Framingham Heart Study (FHS) 10-year prognostic algorithm: The Framingham algorithm measures projected 10-year risk of CVD events using gender-specific Cox proportional-hazard regression models that incorporate age, total cholesterol, high-density lipoprotein (HDL) cholesterol, systolic blood pressure, antihypertensive medication use, smoking and diabetes status (D'Agostino et al., 2008). The Framingham algorithm has good predictive validity for CVD events including coronary heart disease, stroke, peripheral artery disease, or heart failure (D'Agostino et al., 2008), with estimated population risk strongly associated (goodness of fit: $R2$ = 0.84) and in agreement with observed risks (h = 0.84; 95% CI 0.41-1.26) (Eichler, Puhan, Steurer, & Bachmann, 2007). Although there is debate regarding the generalizability of the Framingham algorithm among diverse groups (Goff et al., 2013), risk scores are generally well calibrated to predict coronary events and the Framingham risk algorithm is frequently used as an assessment tool in clinical guidelines (Wood et al., 2005). Outliers were identified and winsorized using the outlier labelling rule; FU + 1.5(FU — FL) and log transformations were applied to correct for positive skew (Table 1).

New Zealand 5-year CVD Risk: New Zealand specific 5-year CVD risk scores were calculated using local clinical guidelines (R. Jackson, 2000). Risk scores are derived from charts which consist of a matrix of cells. Each row relates to bands of SBP, and each column relates to total-HDL cholesterol ratio. Each cell corresponds to projected 5-year CVD risk in 5% increments ranging from <5%->30%, with different matrices for the presence/absence of diabetes, smoking, gender, and for each decade of age from 30–70 years. NZ risk scores have good sensitivity and specificity (Jones et al., 2001). Participants were allocated a risk score based on the mid-point of their assigned risk category, i.e. if categorized as 15-20% risk, they were given a score of 17.5%. As with the Framingham scores, outliers were identified and winsorized and log transformations applied (Table 1).

Ten-year atherosclerotic cardiovascular disease (ASCVD) risk scores: The American College of Cardiology (ACC)/American Heart Association (AHA) Pooled Cohort Risk Equation for estimating atherosclerotic cardiovascular disease (ASCVD) (Goff et al., 2013) was developed to improve generalizability among non-white samples and to capture risk of both cardiac events and stroke. ASCVD scores are based on age, sex, cholesterol, SBP, smoking and diabetes status. Again, outliers were winsorized and log transformations applied (Table 1).

Demographic and bio-behavioral components of projected CVD risk calculations:

Cholesterol: Immediately following blood draws, a 5mL vacutainer of plain blood was transported to the local hospital laboratory facility (LabPlus, Auckland City Hospital) for analysis of total cholesterol, HDL cholesterol, low density lipoprotein (LDL) cholesterol and triglycerides in non-fasting plasma. Analyses were initiated within 45 minutes of blood draws and completed using standard hospital procedures (Table 1).

Systolic Blood Pressure (SBP): Participants sat quietly for three minutes before blood pressure readings were collected using an automated Dinamap V100 vital signs monitor. Blood pressure was measured using the right arm, which was placed on a desk, at approximately heart height. SBP was recoded as the average of two consecutive readings (Table 1).

Self–Reported Risk Measures: Age, sex, antihypertensive medication use, physician diagnosed diabetes, and current smoking status were self-reported (Table 1).

Emotional and Social Covariates

Positive Affect (PA): The 36-item, trait Differential Emotions Scale Version-IV (DES-IV) (Izard, Libero, Putnam, & Haynes, 1993) was used to assess trait PA. Respondents reported their day to day experiences on items such as; "how often do you feel happy" using 5-point scales ranging from rarely/never, to very often. The DES-IV has good construct validity and has been used in a range of ages in community and clinical samples (Boyle, Helmes, Matthews, & Izard, 2015). Scores from the positive emotion subscales were aggregated to generate a total PA score (α = .78) (Table 1).

Depressive Symptoms: The Centre for Epidemiologic Studies Depression Scale (CES-D) is a 20-item self-reported measure of depressive symptoms designed to be used in the general population (Radloff, 1977). The CES-D has good reliability and validity (Orme et al., 1986), in the present study α = .85 (Table 1).

Loneliness: The University of California, Los Angeles (UCLA) Loneliness Scale (Version 3) is a 20-item scale assessing subjective loneliness and isolation (D. W. Russell, 1996). Participants rate items such as "How often do you feel close to people?" (reverse scored) on a scale from 1 (Never) to 4 (Often). The scale has good reliability and validity (D. W. Russell, 1996). In the present study α =.91 (Table 1).

Expressive Skill: Participants deliberately facially expressed 10 basic emotions (happiness, sadness, anger, disgust, interest, fear, guilt, embarrassment, shame and contempt) as quickly and accurately as possible. A TrueVision HD integrated webcam recorded expressions as jpg files (mean size = 24.67 kb). Happy expressions were scored using Noldus FaceReader™ software version 5.0 (Loijens et al., 2014), which scores expressivity based on facial muscle contractions, assigning a value between 0 and 1 for each of six discrete emotions (happiness, sadness, surprise, anger, fear, disgust) as well as neutral. A perfect 1, for happiness, for example, would indicate a large Duchenne smile defined by strong movement of the facial action units corresponding to the orbicularis oculi and the zygomatic major, indicative of sincere positive emotion. FaceReader has good construct validity and accuracy when compared with manually coded scores (A. S. Cohen et al., 2013; Lewinski, 2015). Skill in expressing positive emotion was scored by dividing the 'happy' score by the sum of the total expressivity in the 'happy' photograph. This generates positive expressivity scores that are independent of general or trait expressivity (Table 1). Note that all results were the same when the raw score 'happy' score was used without adjusting for general expressivity.

Effort: To ensure participants attempted to generate accurate expressions during the photo task they used a scale from 1 (I did not try at all) to 7 (I tried really hard) to indicate their degree of effort when producing expression of target emotions (mean = 5.8, SD = 0.96). Although not included in the present analysis due to a relatively small sample size, all results are the same when the degree of effort is co-varied.

9.5.4 Analytic Approach

Univariate correlations were run to test associations between study variables. Following this, linear regressions were run on each of the three CVD risk scores. In each case, PES scores were entered in Step 1, followed by potential confounds; sex, PA, depressive symptoms, and loneliness in Step 2. Finally, the skill by sex interaction term was entered in Step 3. To compute interaction terms, PES scores were z-standardized and multiplied by the dichotomous sex scores (men = 0, women = 1). Where appropriate, simple slopes analysis was used to deconstruct interactions.

9.6 Results

9.6.1 Correlations

Correlations

Univariate correlations between study variables revealed that greater PES was associated with lower NZ 5-year and ASCVD 10-year risk scores, and was marginally associated with lower Framingham 10-year risk scores. As would be expected, all three risk scores were positively correlated with one another. PA and depressive symptoms were negatively correlated, while loneliness was positively correlated with depression and negatively correlated with PA (see Table 2).

Table 9.2 Zero order correlations between trait affect, positive expressive skill, sex, and CVD risk variables

		1	2	3	4	5	6	7
1	Sex (0 = male) [a]							
2	Framingham 10 year risk [b]	-.05						
3	NZ 5 year risk [b]	-.19[ƚ]	.86***					
4	ASCVD 10 year risk [b]	-.15	.87***	.89***				
5	Depressive Symptoms [b]	-.04	-.10	-.05	-.04			
6	Positive Affect [b]	.05	.15	.12	.08	-.57***		
7	Loneliness [b]	-.03	.09	.06	.16	.62***	-.53***	
8	Positive Expressive Skill [b]	.08	-.21[ƚ]	-.35***	-.28*	.01	.03	-.03

*** *p* < .001, ** *p* < .01, **p* < . 05, ƚ *p* < .10

[a] Spearmans correlation coefficients

[b] Pearsons correlation coefficients

9.6.2 NZ 5-year Projected CVD Risk

Entering PES in the first step produced a significant model, F (1, 80) = 11.17, p = .001, explaining 12% variance in risk scores. As expected, PES predicted lower CVD risk scores (β = -.35, p = .001). The addition of covariates; sex, PA, depressive symptoms, and loneliness in Step 2 also produced a significant model, F (5, 76) = 3.75, p = .004, explaining a further 8% variance in risk scores, although the *F*-change was not significant, $F\Delta$ (4, 76) = 1.78, *p* = .14. PES continued to predict lower projected risk (β = -.33, *p* = .002), and being male was associated with marginally higher projected risk (β = -.20, *p* = .064). The inclusion of the sex-by-skill interaction term in the final step again produced a significant model, *F* (5, 71) = 4.92, *p* = .001, explaining a further 8% variance in risk scores, $F\Delta$ (6, 75) = 4.54, *p* = .010. PES continued to predict lower CVD risk scores (β = -.81, $p < .001$), however, this main effect was moderated by an interaction with sex (β = .55, *p* = .010) (see Table 3). Simple slopes analysis showed that lower PES predicted higher CVD risk scores among men, *t* (19) = -3.93, $p < .001$, but not women *t* (61) = -1.41, *p* = .16 (see Figure 1).

9.6.3 ASCVD 10-year Projected Risk

Entering PES in Step 1 produced a significant model, *F* (1, 80) = 6.74, *p* = .011, explaining 8% variance in risk scores. As expected, greater PES predicted lower CVD risk scores (β = -.28, *p* = .011). The addition of covariates; sex, PA, depressive symptoms, and loneliness in Step 2 also produced a significant model, *F* (5, 76) = 3.16, *p* = .012, explaining a further 10% variance in risk scores, although the change in *F* was marginal, $F\Delta$ (4, 76) = 2.17, *p* = .080; PES continued to predict lower risk (β = -.26, *p* = .017), while loneliness predicted higher risk (β = .35, *p* = .014). The addition of the sex-by-skill interaction term in the final step again produced a significant model, *F* (6, 75) = 4.02, *p* = .002, explaining a further 7% variance in risk scores, $F\Delta$ (1, 75) = 7.05, *p* = .010. Greater PES continued to predict lower CVD risk scores (β = -.74, *p* = .001), and loneliness predicted higher risk (β = .31, *p* = .024). However, the main effect of PES was moderated by an interaction with sex (β = .56, *p* = .010) (see Table 3). Simple slopes analysis showed that lower PES predicted higher CVD risk scores among men, *t* (19) = -3.55, *p* = .001, but not women *t* (61) = -.78, *p* = .44 (see Figure 1).

Table 9.3 Results showing the final step for 3 linear regressions, showing how positive expressive skill (PES) and a PES by sex interaction predict projected CVD risk parameters while controlling for trait positive affect, depressive symptoms and loneliness

	Framingham 10 year risk						New Zealand 5 year risk						ASCVD 10 year risk					
	B	SE	β	*p*	sr^2	95% CI	B	SE	β	*p*	sr^2	95% CI	B	SE	β	*p*	sr^2	95% CI
PES	-1.68	0.62	-0.59	.009	0.08	(-2.92,-0.44)	-0.75	0.19	-0.81	.000	0.15	(-1.13,-0.37)	-1.31	0.37	-0.74	.001	0.13	(-2.05,- 0.58)
Sex	-0.10	0.71	-0.02	.885	0.00	(-1.52,1.32)	-0.32	0.22	-0.15	.147	0.02	(- 0.75,0.12)	-0.44	0.42	-0.11	.298	0.01	(-1.29,0.40)
Positive Affect	0.88	0.82	0.15	.282	0.01	(-0.74,2.51)	0.26	0.24	0.14	.294	0.01	(- 0.23,0.76)	0.41	0.48	0.11	.403	0.01	(-0.56,1.37)
Depressive Symptoms	-0.05	0.05	-0.14	.341	0.01	(-0.16,0.06)	0.00	0.02	-0.03	.813	0.00	(- 0.04,0.03)	-0.03	0.03	-0.12	.391	0.01	(-0.09,0.04)
Loneliness	0.08	0.04	0.27	.059	0.04	(0.00,0.16)	0.02	0.01	0.17	.213	0.02	(- 0.01,0.04)	0.06	0.02	0.31	.024	0.05	(0.01,0.11)
Sex-by-skill interaction	1.50	0.73	0.45	.044	0.05	(0.04,2.95)	0.59	0.22	0.55	.010	0.07	(0.15,1.14)	1.15	0.43	0.56	.010	0.07	(0.29,2.02)

sr^2 = squared part correlations

1 Men = 0, Women = 1

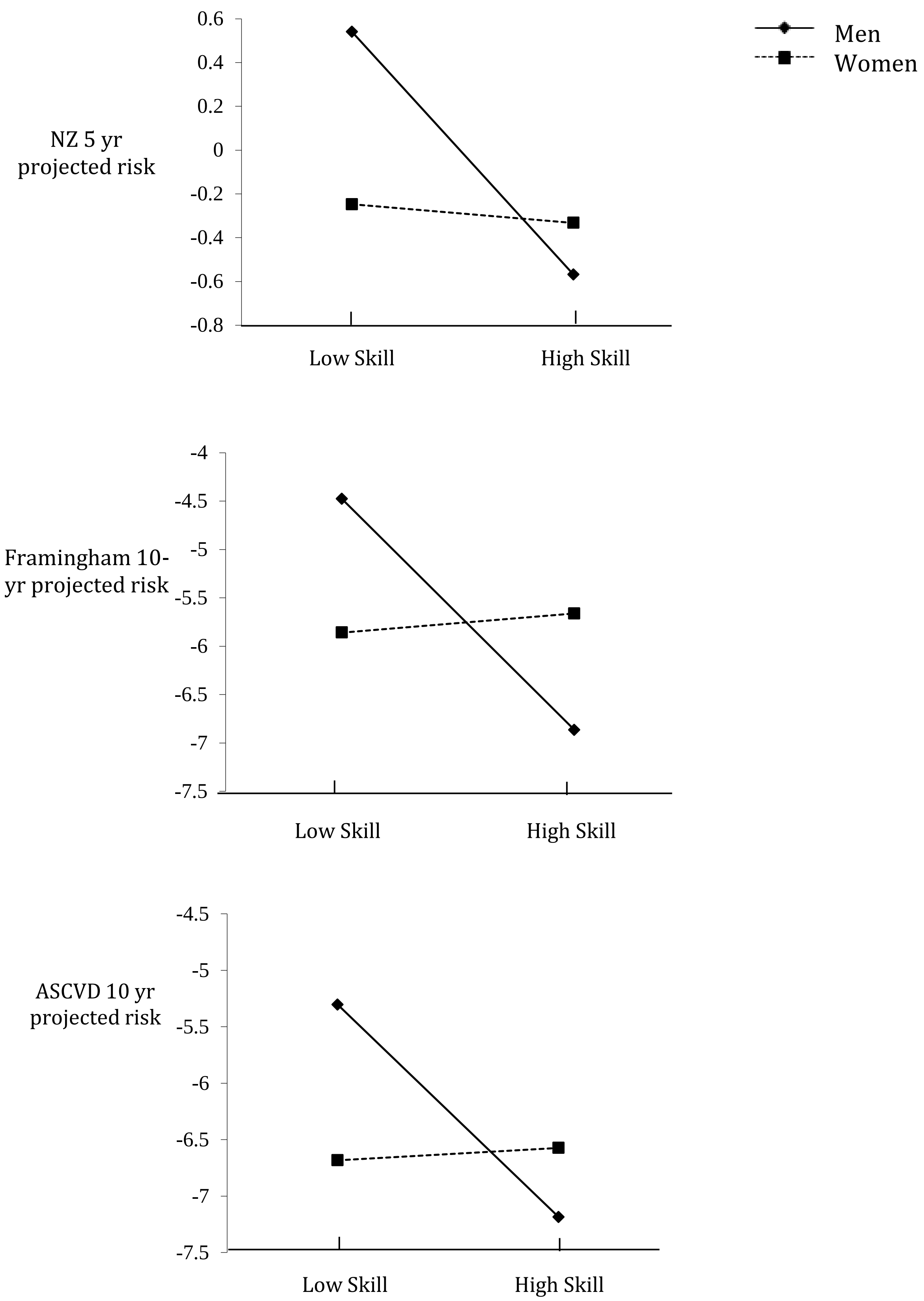

Figure 9.1: Simple slopes showing the interactions between skill in expressing positive emotions and sex in predicting three measures of projected cardiovascular disease risk

9.6.4 Framingham 10-year Projected CVD Risk

Entering PES in the first step produced a marginal model, F (1, 80) = 3.60, p = .061, explaining 4% variance in risk scores. PES marginally predicted lower CVD risk scores (β = -.20, p = .061). The addition of covariates; sex, PA, depressive symptoms, and loneliness in Step 2 also produced a marginal model, F (5, 76) = 2.05, p = .081, explaining a further 8% variance in risk scores, although the change in F was not significant, $F\Delta$ (4, 76) = 1.64, p = .17. PES continued to marginally predict lower risk (β = -.20, p = .073), and loneliness predicted higher risk (β = .30, p = .039). The addition of the sex-by-skill interaction term in the final step did produce a significant model, F (6, 75) = 2.48, p = .030, explaining a further 5% variance in risk scores, $F\Delta$ (1, 75) = 4.19, p = .044. PES predicted lower CVD risk scores (β = -.59, p = .009), however, the effect of PES was moderated by a significant interaction with sex (β = .46, p = .044) (see Table 3). Simple slopes analysis showed that lower PES predicted higher CVD risk scores among men, t (19) = -2.69, p = .009, but not women t (61) = -0.52, p = .61 (see Figure 1).

9.7 Discussion

Positive emotionality and the tendency to express positive emotion have been associated with lower CVD risk (Davidson et al., 2010; Howell et al., 2007; Pressman & Cohen, 2005). To this, the present report adds the possibility that the *ability* to express positive emotion also has ties to measures of cardiac risk. As expected, greater ability to express positive emotion was associated with lower cardiac risk scores on three metrics, even after controlling for PA, depressive symptoms, and loneliness. Additional analyses suggested that this effect was primarily evident among men. Below, we discuss these results more fully, consider possible interpretations, and offer directions for future study.

The finding that the *ability* to express positive emotion was associated with lower CVD risk scores is consistent with evidence that trait positive expressivity is associated with lower cardiac risk (Davidson et al., 2010) and smile intensity predicts longevity (Abel & Kruger, 2010). Interpretatively, the ability to *deliberately* express positive emotion may reflect differences in an underlying capacity to self-regulate, which in turn has links with better health outcomes (Kubzansky et al., 2011; Potijk et al., 2016). Additionally, positive expressive skill may correspond with lower risk via social mechanisms, increasing available support and co-operation (Owren & Bachorowski, 2001) and reducing risk associated with social isolation (Valtorta et al., 2016).

However, moderation analyses suggested that the links between expressive skill and risk scores were predominantly evident in men. Interpretatively, although there were no clear sex differences in skill scores, such metrics may be more closely associated with risk in men due to either lower skill and/or higher risk scores in this group. Alternatively, positive expressive skill may serve a protective function that is more salient among men, by offsetting a typically less facilitative style of emotional signalling. Compared to women, men are more likely to express emotions that increase social distance (Hall, Carter, & Horgan, 2000), and respond to stressors with egocentricity and a 'fight or flight' response, potentially increasing CVD risk via allostatic load and social factors (Tomova, von Dawans, Heinrichs, Silani, & Lamm, 2014; Valtorta et al., 2016). Conversely, positive expressions signal a willingness to interact and co-operate (Owren & Bachorowski, 2001), and the *ability* to deliberately signal positive emotion (regardless of felt emotion), may buffer CVD risk by improving social support, facilitating conflict resolution, and speeding autonomic recovery (e.g. Kraft & Pressman, 2012). Evidence that the links between psychosocial factors and disease risk are more apparent among men than women (Yang et al., 2013), may imply that the *cost* of expressive skill deficits might be higher for men.

9.8 Limitations and future directions

The present data have several limitations. Findings in a predominantly white sample cannot be generalized to other groups. Likewise, participants self-selected into the study, and CVD risk factors were relatively low. Selection biases (particularly among men) may be strong for a study titled 'Emotions and Health', and the present sample may not be representative of the broader population. Men were under-represented in the present sample, and, marginal effects in some models may indicate that the study was underpowered. Further studies in larger, more representative, gender-balanced samples are needed to confirm these findings.

Additionally, despite controlling for several established confounds, the cross-sectional design means that third variable confounds are nonetheless possible and the ability to express positive emotion may be confounded with the ability to generate positive affect. Additionally, the direction of the relationship remains unclear. It is, for example, possible that men in poorer health are less able to signal positive emotions. Relatedly, skill deficits might reflect differences in motivation, attention, or system fatigue, although controlling for reported effort did not influence the present findings.

Further, it is important to note that risk metrics cannot be generalized to actual cardiac events, and future work is needed to test whether expressive skills predict cardiac morbidity or mortality. Rather, risk metrics reflect a combination of biological, demographic, and behavioral risk factors, and a single risk factor (or group of factors) may be responsible for the observed link between expressive skill and risk scores. Although correlations between skill scores and individual risk metrics were not significant, and did not indicate that any single metric (or group of metrics) was responsible, future studies identifying the specific risk factors that are most strongly associated with expressive skills would help to identify the mechanisms by which expressive skills are associated with CVD risk scores. This noted, risk scores are only reliable predictors of outcome among middle aged and older samples (D'Agostino et al., 2008; Dawber, Meadors, & Moore Jr, 1951; Lloyd-Jones et al., 2004) and studies in younger samples and student groups are not well suited to the examination of links between expressive skills and cardiac risk algorithms.

Finally, the ability to signal negative emotions may also be associated with better health outcomes, however several issues prevented exploration of this possibility in the current report. First, in contrast to the positive expressive skill metrics, the negative skill scores were poorly distributed and ill-suited to parametric testing. This may indicate that signalling specific negative emotions is more challenging than showing positivity (at least in this measurement context). Second, participants often tilted their heads of covered their faces while expressing negative emotions, meaning that the FaceReader ™ software was unable to generate valid expressivity estimates for negative expressions for an additional 20 participants (reducing the sample size from 82 to 62). Third, although combining negative skills scores into a single negative affect skill metric did produce a normally distributed aggregate that was associated with lower CVD risk scores, the alpha coefficient was low (α = .15), suggesting that combining these variables is not empirically warranted. Thus, although the present findings are limited to positive expressive skill, it seems likely that skill in expressing negative emotions may also predict health outcomes, and future studies testing this possibility are needed.

Despite limitations, this report provides early empirical evidence that an objective test of the ability to signal positive emotion predicts projected cardiac risk. It extends prior findings linking both trait PA and positive expressivity with health outcomes, and implies that the *ability* to signal positive emotion may underpin some of these links. Given that the biological, behavioral, and demographic risk factors measured here are relevant to other chronic conditions, notably diabetes (Singh et al., 2013; Wulsin, Horn, Perry, Massaro, & D'agostino, 2015), the observed links between skills and CVD risk scores may extend to other health outcomes.

Chapter 10 : Discussion

10.1 Chapter overview

The dispositional tendency to suppress emotion is widely thought to contribute to poorer mental and physical health outcomes. However, as has been argued throughout this thesis, there are reasons to suspect that the links between suppression and health are more complex. Trait expressive regulation is only one component of a broader emotion regulatory construct, which is also comprised of regulatory knowledge and skills. In addition to having methodological and conceptual advantages over trait measures, early evidence suggests that objectively assessed regulatory skills/abilities serve a protective function, reducing vulnerability to stress (Bonanno, 2005; Bonanno et al., 2004; Gupta & Bonanno, 2011; Levy-Gigi et al., 2016; Westphal et al., 2010). As such, although it is plausible that ability metrics will also predict physical health outcomes, prior to the current body of work, this possibility had not been subject to systematic empirical testing.

In addressing this gap in the literature, the studies presented throughout this thesis were designed to investigate the overarching question of whether performance-based tests of the ability to regulate the expression of emotion were associated with physical health outcomes. Additional questions regarding the *types* of health indices that might be associated with skill-based metrics, and the specific operationalisations of regulatory ability that best predict health were also addressed. To this end, three cross-sectional laboratory studies investigated the ways in which diverse operationalisations of regulatory ability predicted three categories of health outcome; self-reported health, objective physiological parameters, and projected disease risk.

Although each report documents specific links between regulatory abilities and health, and the different reports have been adjusted in response to the peer review process, findings can be broadly synthesised into three key contributions. First, across all three studies, performance-based tests of the ability to regulate the outward expression of emotion predicted physical health outcomes. Second, in considering different *types* of health outcomes, data revealed that regulatory abilities predicted self-reported health and wellbeing, objective physiological and biological parameters, and clinically relevant disease risk. Finally, rather than any single skill-based metric predicting outcomes, findings revealed that diverse operationalisations of expressive regulatory ability were associated with indices of physical health.

These core contributions are discussed as providing evidence consistent with the notion that the ability to flexibly regulate the visible expression of emotion (including the ability to suppress expressivity) is a useful manner in which to view and measure emotion regulation in the context of physical health. Throughout this chapter, implications for theory are discussed and possible mechanisms and clinical applications for these findings are outlined, before general limitations and areas for future research are considered.

10.2 Do ability metrics predict outcomes?

This initial section addresses the first general question of whether ability-based metrics of expressive regulatory skill are a useful way in which to consider emotion regulation in the context of health. To this end, the primary empirical contributions from across this thesis are summarised and integrated with prior work. Doing so demonstrates that a shift away from traits, to encompass the investigation of skills, should allow for a more comprehensive and less problematic examination of the links between expressive regulation and health.

As noted, findings from across this thesis revealed that the objectively assessed *ability* to flexibly regulate the expression of emotion predicted better health outcomes. Specifically, greater expressive regulatory skill predicted lower depression and anxiety (Chapter 8), lower symptom interference, (Chapter 6), and better perceived health (Chapter 8). Although relationships were more complex, skill-based metrics were also associated with objective physiological parameters including HRV (Chapters 6 and 7), and immunoregulatory molecules (Chapter 8), and greater skill predicted lower disease risk metrics (Chapter 9). Furthermore, links to positive outcomes were consistent across two distinct scoring methods. Specifically, expressive skill for Studies 1 and 3 was calculated using automated, face coding software, whereas Study 2 scores were generated by trained human coders. Overall, findings of consistent links to outcomes across diverse operationalisations, samples, and coding strategies, lends methodologically rigorous support to the claim that individual differences in emotion regulation predict physical health outcomes. This then has the implication that an abilities-based approach offers a viable alternative to the dominant, trait-based approach to the assessment of emotion regulation.

As such, the first general contribution of this work lies in building the evidence base linking expressive regulatory skills with outcomes. The past decade has seen the development and deployment of expressive skill paradigms in which participants are required to alter the visible expression of emotions. Although informative, work using these paradigms emanates from a small number of research groups, and although there are exceptions, studies have been predominantly based on student samples, with a general focus on psychological outcomes (e.g. Bonanno et al., 2004; Galatzer-Levy et al., 2012; Westphal et al., 2010). In contributing four empirical reports demonstrating that links are evident beyond student samples, and that expressive regulatory skills predict a diverse range of physical health parameters, the studies in this thesis build the evidence base supporting the utility of adopting a skills-based approach.

In addition to replicating and extending prior work, this contribution also calls into question the general tendency to focus on experiential rather than expressive emotion regulation. Different theoretical perspectives place varying degrees of emphasis on the importance of emotional expressions. At one end of the spectrum, discrete approaches assert that the regulation of expression plays a central role in daily social interactions (Campos et al., 1989; Keltner, 1995; Rozin, Lowery, Imada, & Haidt, 1999), whereas investigators that characterise emotions as occurring along orthogonal dimensions of valence and arousal (e.g. Barrett, 2006) typically fail to acknowledge the expressive component of the emotion regulation construct (Bonanno et al., 2004; Coifman & Bonanno, 2009).

Perhaps as a result of this, self-reported measures of emotion regulatory ability are generally geared towards the assessment of feeling states as opposed to expressive behaviour. For example, regulatory ability is commonly assessed using the Difficulties with Emotion Regulation Scale (DERS)(Gratz & Roemer, 2004). However, of the 36 DERS items, only 3 refer to the regulation of behaviour, and none address difficulties in the regulation of facial expressions (see Gratz & Roemer, 2004). As such, although emotional expressions can be objectively assessed, the investigation of regulatory abilities has predominantly focused on regulating underlying feeling states, as opposed to the regulation of facial expressivity (e.g. Abravanel & Sinha, 2015; Berna et al., 2014; Innamorati et al., 2016; Salters-Pedneault, Roemer, Tull, Rucker, & Mennin, 2006; Tull & Roemer, 2007; Tull, Weiss, Adams, & Gratz, 2012; Whiteside et al., 2007; D. P. Williams et al., 2015).

Another reason for this tendency to focus on underlying emotion, appears to be that it is often assumed that the primary goal of emotion regulation is to alter the underlying emotional *experience* (see Consedine & Mauss 2014 on the question of hedonic regulation); however the present findings suggest that the regulation of emotional *expressivity* is also important. In focusing on the assessment of expressive regulation, while controlling for potential third variables that might index experiential elements, the studies in this thesis demonstrate that the observed links between regulatory skill and health are specific to the *expression* of emotion, and not attributable to underling affect, personality, or other confounds.

Interpretatively, because emotional experiences serve an important motivational function, it is likely that there are circumstances in which it is useful to regulate the *outward* expression of emotion while preserving the experiential component and its associated motivating role (e.g. Heilman, Crişan, Houser, Miclea, & Miu, 2010; Panno et al., 2013; Troy et al., 2013). Consistent with this possibility, and in addressing the question of the relative importance of experiential versus expressive regulation, the present findings represent the first evidence that greater ability to regulate the *expression* of emotion (rather than to regulate feeling states) predicts better physical health outcomes.

These data suggest that empirical examinations of the ability to regulate the *outward* signals of emotion are warranted. Unlike experiential regulation which is difficult to measure objectively, assessments of expressive regulatory ability should allow investigators to increase rigor in their operationalisations and build an evidence-base that is more readily interpretable, more suited to the identification of mechanism, and more consistent with theoretical views of the functions of emotions (see Chapter 4).

10.3 What *types* of health outcome are associated with skills?

A second contribution of this thesis lies in examining variation in the health outcomes that are associated with expressive regulatory skills. Identifying the specific health outcomes that are most consistently associated with the ability to regulate the expression of emotion should narrow the range of potential mechanisms responsible, and allow for more targeted investigations. For example, if skills are found to predict symptom reports and perceived health, but not more objective health metrics, it would suggest that psychosocial mechanisms are responsible and/or that skills deficits are a precursor for future health risk. Conversely, evidence of links with more objective markers of physical health status would imply that underlying physiological or biological processes may also be involved.

Although there are numerous ways in which to categorise health outcomes, the studies presented in this thesis are usefully thought of as examining three broad types of health outcomes, with consecutive studies complementing and building on each other in terms of objectivity and/or clinical relevance. Specifically, this thesis assessed links between skills and 1) self-reported health and wellbeing, 2) biological and physiological parameters, and 3) projected disease risk. Below, the evidence that skills predict each of these outcomes is summarised, and the ways in which findings contribute to the question of why expressive regulatory ability might be important for physical health are discussed.

Self-reported health and wellbeing

Self-reported physical symptoms are central to daily functioning and important predictors of wellbeing (Barsky et al., 2001; Kroenke et al., 1994), while self-reported global health is a reliable predictor of mortality, even when controlling for objective health indices (see Idler & Benyamini, 1997 for a review). As such, evidence that greater skill in regulating expressivity predicted fewer symptoms (Chapter 8), lower symptom interference (Chapter 6), and greater self-reported global health (Chapter 8), offers convergent evidence that skill-based metrics are a useful means of operationalising expressive regulation in the context of physical health.

Although not a central focus of this work, findings that regulatory skills also predicted fewer depressive symptoms and lower anxiety are consistent with evidence from other groups showing that expressive skills predict better psychological wellbeing (Bonanno & Burton, 2013; Bonanno et al., 2004; Gupta & Bonanno, 2011; Rodin et al., 2017; Westphal et al., 2010). Work using clinical samples has repeatedly demonstrated that depression is associated with reduced facial expressivity (Berenbaum & Oltmanns, 1992; Gaebel & Wölwer, 1992; Jaeger, Borod, & Peselow, 1986; Sloan, Strauss, Quirk, & Sajatovic, 1997). As such, although the direction of the relationship remains unclear, evidence that deficits in the *ability* to accurately signal discrete emotions predicted greater depressive symptoms in a community sample, may suggest that reduced expressivity is a prodromal symptom or risk factor in the development of depression among non-clinical groups. As is discussed more fully below, a common mechanism such as social difficulties, dysregulated stress responding, or inflammation may be responsible for both depressive symptoms and expressive skill deficits.

Physiological parameters

However, perceived health is only one means of assessing physical wellbeing, and investigating whether skills also predict more objective health indices not only increases the rigor and scope of the outcomes being assessed, but also provides additional clues regarding the underlying mechanisms. Therefore, in addition to self-reported outcomes, the empirical studies in this thesis tested links between expressive regulatory skills and two objective physiological parameters: HRV and immunoregulatory molecules.

In addition to predicting cardiac health (Dekker et al., 2000), HRV has been associated with both self-reported emotion regulation (D. P. Williams et al., 2015), and trait expressivity (Pu et al., 2010). Furthermore, both the polyvagal theory (Porges, 1997, 2007) and the neurovisceral integration model (Thayer & Lane, 2000; Thayer & Lane, 2009) suggest that the ability to regulate the expression of emotion has close links with autonomic processes that are indexed by HRV. Given this background, findings that skills are associated with higher (or marginally higher) HRV (Chapters 6 and 7) suggest that regulatory skills may have their roots in physiological and neural processes. Moreover, lower HRV among those with poorer skill may have implications for long term cardiac risk (Dekker et al., 2000; Thayer et al., 2012) and it is possible that a common mechanism underlies the degree of flexibility in both psychological and physiological responding.

In addition to HRV, accruing evidence suggests that immune parameters and social behaviour co-regulate one another (Eisenberger, Moieni, Inagaki, Muscatell, & Irwin, 2016). As such, although links were mixed (Chapter 8), evidence that regulatory skills also predicted immunoregulatory molecules is broadly consistent with this view, while concurrently supporting the possibility that inflammatory processes may be implicated in the links between emotion regulation and health (Appleton, Buka, Loucks, Gilman, et al., 2013; Kendall-Tackett, 2010; Yudkin et al., 2000). For example, elevations in IL-8 have been associated with *greater* resilience to anxiety and distress (Janelidze et al., 2015), and the present findings that skill in signalling disgust predicted both lower anxiety, and higher IL-8 offers early evidence that expressive skills have theoretically consistent links with both immune parameters and psychosocial outcomes that warrant further examination. Although findings pertaining to individual immunoregulatory molecules must be interpreted with caution, evidence that skills were associated with both HRV (Chapters 6 and 7) and immune parameters (Chapter 8), suggests that physiological processes may be at least partly responsible for the links between expressive skills and physical health outcomes.

Disease risk metrics

Finally, evidence that expressive regulatory skills predicted projected CVD risk scores offer an initial demonstration that the ability to regulate the outward expression of emotion has implications for clinically relevant health outcomes. Projected CVD risk metrics are derived from a combination of demographic, behavioural, and clinical risk factors including blood pressure, cholesterol, smoking, and body mass index (e.g. D'Agostino et al., 2008)(see also Chapter 9). As such, projected risk scores provide a holistic measure of current health status that is likely to correspond with a more general profile of elevated disease risk.

Interpretatively, although skill deficits may increase CVD risk scores via behavioural or demographic factors, findings that skills also predicted both HRV (Chapter 6 and 7) and inflammation (Chapter 8) suggest that sustained or cumulative strain on the cardiovascular system may be contributing to higher blood pressure and/or cholesterol among those with poorer regulatory skill. Although not directly tested, these biological risk metrics may be driving up CVD risk sores. Future work identifying the specific cardiac risk factors that are most reliably associated with skills would further illuminate the pathways linking skills with cardiac outcomes.

Concluding remarks

In examining the links between expressive regulatory skill and broad categories of physical health outcome, consistent *positive* links between skills and health were apparent in both self-reported and projected disease risk measures. Furthermore, although links between expressive skills and both HRV and inflammation were complex, evidence that skill metrics predicted higher HRV across two separate studies provides compelling evidence that skill-based metrics have important links with physiological processes that warrant further investigation. Moreover, findings that skills predict objective, clinically relevant estimates of CVD risk provide much needed evidence that the *ability* to regulate is associated with better physical health. Overall, in taking initial steps towards identifying the classes of health outcome that are best predicted by regulatory skills, the work in this thesis indicates that rather than showing links with any single *type* of outcome, skills are associated with a diverse range of physical health metrics including self-reported health, objective indices of physical functioning, and clinically relevant disease risk.

10.4 Which skills predict outcomes?

In addition to examining the specific health outcomes that are predicted by skills, another means of building a clearer picture of how regulatory abilities predict health lies in identifying whether specific expressive skills are differentially predictive of different outcomes. As analyses conducted in this thesis make clear, there are multiple ways of operationalising the ability to regulate expressivity. As noted, if particular skill-based metrics are found to be more (or less) predictive of health, this would streamline the focus of inquiry and provide further clues regarding the nature of the underlying mechanisms.

In exploring the possibility that particular skills may be differentially associated with health, the studies represented in this thesis tested the predictive utility of three distinct skill-based operationalisations; the ability to flexibly regulate the expression of *felt* emotions (Chapter 6), performance tests of emotional knowledge (Chapter 8), and the ability to signal specific emotions in the relative absence of underlying affect (Chapters 7, 8 and 9). In taking preliminary steps towards identifying the specific *types* of skills that might best predict health, findings regarding these diverse operationalisations are discussed below.

Expressive flexibility and outcomes

The first operationalisation of skills used in this thesis was derived from an established laboratory paradigm assessing the degree to which a person is able to both enhance and suppress expressivity during exposure to emotion eliciting stimuli; the expressive flexibility paradigm (e.g. Bonanno et al., 2004; Gupta & Bonanno, 2011; Levy-Gigi et al., 2016; Rodin et al., 2017; Westphal et al., 2010). In adding to the body of work based on this paradigm, the present thesis provides early evidence that in addition to the general magnitude of positive/negative expressivity, links to health may be specific to the ability to regulate particular discrete emotions.

As mentioned, prior work has used a valence-based approach to assessment, and scored expressivity based on the magnitude of positive/negative expressions (Bonanno et al., 2004; Demaree, Pu, et al., 2006; Demaree, Schmeichel, et al., 2006; Westphal et al., 2010). However, in keeping flexibility scores for discrete emotions separate (Chapter 6) it was demonstrated that the ability to flexibly regulate the expression of joy and sadness (but not anger) predicted lower symptom interference (Chapter 6).

Although some these differences may reflect the different coding strategies used in Studies 1 and 3 versus Study 2, and the underlying structure of expressive regulatory skills is unclear meaning that it is too early for definitive commentary as to whether specific skills correspond with specific health outcomes, the present findings suggest that not all regulatory skills predict health in the same way. Indeed, evidence that skill in regulating specific emotions predicted distinct health outcomes, suggests that more nuanced assessments at the level of discrete emotions (rather than valence-based approaches) are warranted. Most broadly, in terms of the initial questions inspiring this thesis, although the suppression of emotion has long been considered a risk factor for poorer outcomes (Chapter 2), evidence that the ability to flexibly (enhance and *suppress*) expressions predicted *better* health outcomes, suggests that links between suppression and poorer health may have been overstated.

Ability-knowledge and outcomes

In addition to flexibility metrics, the tripartite model described earlier (Chapter 4) suggests that successful regulation hinges upon emotional knowledge/intelligence (Mikolajczak, 2010). In this view, regulatory knowledge and skills work in tandem to coordinate successful expressive regulation, whereby knowledge regarding the most appropriate regulatory behaviour will influence the ways in which expressions are regulated (Mikolajczak, 2010; Mikolajczak et al., 2009). Empirically however, although trait self-reported knowledge has been associated with better physical health, self-reports of knowledge are only weakly correlated with ability-based measures, and these two assessment strategies appear to capture distinct constructs (Brackett & Mayer, 2003).

As such, findings that performance-tests of knowledge predicted fewer physical symptoms and lower IL-8 (Chapter 8) represent early evidence that objective, knowledge-based metrics also have ties to physical health outcomes. However, the reasons for these associations and the underlying pathways have not been investigated. As such, future work testing the degree to which knowledge mediates or moderates links between performance-based expressive skills and outcomes should provide additional insight into the ways in which these performance-based measures of regulatory ability relate to one another in the prediction of health outcomes.

Deliberate expressions and outcomes

Finally, in investigating the capacity to rapidly signal *specific* emotions in the absence of underlying affect, the third way in which skills were operationalised was via a novel expressive skill paradigm. In this more portable operationalisation, participants were required to facially express discrete emotions in the absence of emotion eliciting stimuli.

In addition to practical considerations, theory suggests that social interactions are characterised by the rapid signalling of socially appropriate expressions in a manner that transmits information about the sender and the wider environmental context, potentially in the absence of the associated feeling state (Blair, 2003; Fridlund, 2014; Hareli & Hess, 2012). It therefore seemed likely that the ability to rapidly signal specific discrete emotions should also be associated with better outcomes, including physical health.

Consistent with this view, findings from across this thesis demonstrated that skill in expressing specific discrete emotions predicted higher HRV (Chapter 7), lower depression and anxiety, better self-reported physical health (Chapter 8), lower CVD risk (Chapter 9), and showed mixed links with immunoregulatory molecules (Chapter 8). In demonstrating that the ability to rapidly and accurately signal discrete emotions is a reliable predictor of health indices, this body of work extends links beyond flexibility and knowledge metrics, and broadens the evidence base linking diverse regulatory skills with outcomes.

Because the ability to signal specific emotions is fundamentally distinct from the ability to enhance or suppress the expression of underlying affect, these skills may draw on distinct cognitive and physiological resources and may be differentially associated with physical health. In addressing this possibility, links with outcomes were reviewed across operationalisations in which an accompanying emotional experience was/was not present. This revealed that although skills in regulating the expression of sadness and joy predicted similar outcomes across operationalisations, this was not the case for anger. Instead, greater skill in *flexibly regulating* anger predicted marginally lower (Chapter 6) while skill *signalling* anger (when one was not actually feeling angry) predicted higher HRV (Chapter 7). Although it is premature to make conclusive statements regarding which operationalisation is a *better* predictor of health, this pattern does suggest that distinct operationalisations of skill may be differentially associated with physical health parameters.

Finally, given that a key barrier to the assessment of behaviour is the substantial resource required to collect, clean, and code behavioural data, findings that this more portable, rapid, and potentially automatable operationalisation of expressive skill showed links with physical health outcomes has implications for future work at the emotions-health interface. In addition to this, findings that skills predicted similar outcomes across both human and automated coding methodologies, suggests that automated software is a viable alternative to human coding; and the increasing availability of face-coding software streamlines this process even further. Overall, in making the assessment of skills more feasible and cost effective (photographic data are considerably faster to collect, process and code), this novel task should encourage the inclusion of skill-based metrics in the investigation of links between emotion regulation and health.

Links between discrete emotions and outcomes

In addition to the possibility that different operationalisations of skill are differently predictive of outcomes, there is also some evidence for specificity in the relationships between specific discrete emotions and physical health. As outlined above, for example, skill in regulating sadness predicted better self-reported health and higher HRV across two separate studies (Chapters 6 & 8). Additionally, while so-called "basic" emotions such as sadness and joy were each associated with health metrics across multiple samples and operationalisations, other emotions such as fear, surprise and guilt showed few, if any links to physical health (Chapters 7 and 8). Furthermore, although skill in signalling joy predicted lower concentrations, skill in signalling hostile emotions (contempt and disgust) predicted higher concentrations of immunoregulatory molecules (Chapter 8). These findings indicate that links between skills and health are not uniform, and some expressive skills (for specific discrete emotions) may have closer and more consistent positive/negative links with physical health than others. Although it is possible that this preliminary indication of specificity represents a measurement issue and/or the commonality of certain expressions in daily life, further investigation of discrete emotions appears warranted.

In a similar vein however, it is worth noting that the ability to regulate the expression of happiness showed the most consistent, positive links with health outcomes; predicting better self-rated health (Chapters 6 and 8), lower inflammation (Chapter 8), and lower CVD risk (Chapter 9). Although numerous studies have linked positive expressivity with better outcomes (e.g. Abel & Kruger, 2010; Davidson et al., 2010; Harker & Keltner, 2001; Hayashi et al., 2016), the present findings offer new interpretive possibilities for such work. Specifically, although prior work is generally interpreted as evidence that positive *emotions* contribute to better outcomes (Abel & Kruger, 2010; Harker & Keltner, 2001; Hertenstein et al., 2009), the current findings show that links between positive expressivity and outcomes persistent even when controlling for state (Chapter 6), and trait PA (Chapter 9). It is therefore reasonable to suggest that measures of positive expressivity may be capturing regulatory skills as opposed to underlying or dispositional feeling states. Hence, rather than interpreting the expression of positive emotion as necessarily a proxy for underlying affect, work in this tradition might benefit from considering the possibility that expressive regulatory skills partially underpin the links between greater dispositional positive expressivity and better health outcomes.

Concluding remarks

However, although skill in signalling happiness was found to be a reliable predictor of outcomes, it is important to note that work from across this thesis shows that the links between expressive skill and health are not specific to any single strategy (such as expressing positive emotion), but are apparent across numerous skill-based operationalisations. Links to health were evident across positive and negative emotions, across two major expressive regulatory strategies (enhance/suppress), when underlying emotional experience was both present and absent, and across three distinct operationalisations of skill. The demonstration that the ability to flexibly (enhance and suppress) expressivity is associated with *better* physical health outcomes is clearly at odds with the suggestion that suppression is inherently deleterious. It is, however, consistent with recent theoretical advances which argue that rather than any particular regulatory tactic being universally beneficial or harmful, the ability to flexibly apply a diverse range of regulatory strategies may be a better way of thinking about healthy regulation in the context of physical health.

10.5 Potential mechanisms

Given the absence of a clear empirical base, determining exactly *why* emotion regulatory skills so consistently predicted physical health indices is not easy. The current program of research was designed to provide "proof of principle," and was consequently not well-geared to test potential mechanisms. This limitation and caveat noted, several interpretative possibilities are briefly discussed below.

Prior empirical work offers some useful guidance regarding potential mechanisms. Studies have shown that regulatory skills most reliably predict outcomes in the context of trauma or cumulative stress (Galatzer-Levy et al., 2012; Rodin et al., 2017; Westphal et al., 2010), potentially increasing resilience via social processes (Coifman & Bonanno, 2009). In theory, rather than being primarily driven by *internal* affective or mood states, the capacity to up- and down regulate the expressive constituents of emotion may allow a person to adjust behaviour in a manner that is sensitive to contextual demands (Bonanno & Burton, 2013; Coifman & Bonanno, 2010). Regulating expressivity in contextually-appropriate ways may facilitate goal attainment and maintain or enhance social resources (Bonanno & Burton, 2013; Coifman & Bonanno, 2009; Westphal et al., 2010) which subsequently buffer against, and/or facilitate recovery from, the stressors that are thought to damage health (S. Cohen & Wills, 1985; Fredrickson, 2013; O'Donovan & Hughes, 2007).

To illustrate this point, the death of a loved one is a relatively common, but undeniably painful event, frequently inciting prolonged negative emotion such as sadness (Shuchter & Zisook, 1993). Although expressions of sadness serve a socially useful function (Forgas, 2013; Gray, Ishii, & Ambady, 2011; Manstead, Fischer, & Jakobs, 1999), there are times when it is more appropriate to inhibit sad expressions, such when hosting a child’s birthday party or attending a close friend’s wedding (Coifman & Bonanno, 2010). More broadly, because the persistent expression of negative emotion may have a detrimental impact on social resources (Consedine, Magai, & Bonanno, 2002; Coyne, 1976; Keltner, Ellsworth, & Edwards, 1993), the ability to selectively inhibit negative expressions at particular times may facilitate recovery

(Bonanno, 2005; Coifman et al., 2007; Gupta & Bonanno, 2011) by building social resources (Fredrickson, 1998; Fredrickson & Levenson, 1998; Lyubomirsky, King, & Diener, 2005; Mauss et al., 2011), and increasing opportunities for personal growth (Fredrickson, 2013).

In addition to social processes, the facial feedback hypothesis suggests that facial expressions may play an active role in generating or modulating internal feeling states (Davis, Senghas, Brandt, & Ochsner, 2010; Soussignan, 2002; Strack, Martin, & Stepper, 1988; Tomkins, 1962; Zuckerman et al., 1981). For example, manipulating participants' facial expressions to generate smiles has been shown to increase reported PA (e.g. Soussignan, 2002). Likewise, paralysing frown muscles with botulinum toxin appears alter the neural systems implicated in negative feeling states (Hennenlotter et al., 2009), potentially attenuating negative mood, and even facilitating recovery from depression (Finzi & Wasserman, 2006)

Although, recent controversy regarding the replicability of the facial-feedback hypothesis must be acknowledged (Wagenmakers, Beek, Dijkhoff, & Gronau, 2016), it is nonetheless possible that emotional expressions influence neural and autonomic processes (Ekman, Levenson, & Friesen, 1983; Giuliani et al., 2008; Hennenlotter et al., 2009; Lanzetta et al., 1976; Porges, 1997; Soussignan, 2002; Stemmler, 1989), with potential implications for health and wellbeing. For example, deliberate smiles have been shown to facilitate cardiovascular recovery following exposure to a stressor (Kraft & Pressman, 2012). As such, regardless of whether feeling states are altered or not, exerting control over the expression of emotion, and/or signalling positive emotion, may offer a means of down regulating stress reactivity, with potential cumulative benefits for physical health and wellbeing.

An alternative possibility is that the capacity to regulate expressivity is the *product* of healthier physiological system. As was noted earlier, HRV is widely viewed as an index of the degree to which the nervous system is able to flexibly respond to challenges and opportunities in the environment (Thayer & Lane, 2000) and may be a marker of physical health status (Dekker et al., 2000; Thayer et al., 2012). As such, evidence that greater skill is (typically) associated with higher HRV might imply that the capacity to regulate facial expressivity is a symptom of healthier physiological systems that are better equipped to flexibly respond to, and recover from, the impact of daily demands.

Finally, it is also possible that the ability to regulate expressivity is part of the broader capacity to regulate automatic response tendencies and exert control over behaviour more broadly. The capacity to self-regulate has been associated with better engagement in healthy behaviours (see de Ridder et al., 2012 for a review), as well as greater PA and life satisfaction (Hofmann, Luhmann, Fisher, Vohs, & Baumeister, 2014). Given that the regulation of expressive behaviour involves inhibiting automatic responding so that a regulated response can occur (Thayer et al., 2009), the capacity to regulate expressivity may be a proxy for the ability to engage in goal directed behaviour more broadly. As will be discussed however, longitudinal and prospective work clarifying the direction of the links between skills and health is needed in order to better understand the mechanisms and direction of this relationship.

10.6 Applications; a case for skills training

Although mechanisms should ideally be identified before clinical applications are considered, the present findings suggest that regulatory abilities may offer a suitable target for health-promoting interventions. Findings from across this thesis are consistent with the suggestion that the *ability* to employ a diverse range of regulatory strategies may contribute to better physical and psychological wellbeing (Bonanno & Burton, 2013). In light of this, increasing the capacity to both enhance and inhibit the visible aspects of an emotional response might represent an appropriate therapeutic target, not only for those with general mood, anxiety, or impulse control disorders, but also in the context of physical health.

In offering potential avenues for improvement, findings suggest that HRV corresponds with better expressive regulatory skill. As such, interventions that increase HRV using biofeedback (Lehrer et al., 2003), may enhance the capacity to regulate and/or signal emotions. Similarly, third wave therapies such as mindfulness and/or acceptance and commitment (ACT) approaches that encourage deliberate observation of thoughts and experiences in a manner that extricates emotions and cognitions from behaviour (Desrosiers, Vine, Curtiss, & Klemanski, 2014; Farb, Anderson, Irving, & Segal, 2014; Fogarty et al., 2013; Hill & Updegraff, 2012), may increase the capacity to flexibly regulate the expression of emotions.

Although there is some evidence that expressive skills are stable over time (Westphal et al., 2010), future work testing the degree to which regulatory skills are trait-like or can be increased is critical, as is clarification regarding the pathways by which benefits are derived. Likewise, if skill deficits are found to be a precursor or risk factor for the development of poorer physical and psychological outcomes, then skills training may have particular relevance for those identified as being at risk for poor health, such as those with early indications of cardiovascular or inflammatory disease.

Overall, directing attention towards the *behavioural* components of emotion regulation, may offer a therapeutic target that is more amenable to change than underlying feeling states. Findings that regulatory skills predicted a range of better physical and psychological outcomes, including better self-reported health (Chapters 6 and 8), higher HRV (Chapters 6 and 7), lower depression (Chapter 8), and lower CVD risk (Chapter 9) suggest that increasing the capacity to regulate the expression of emotion, and/or engage in other compensatory expressive behaviours may serve a protective role within high risk groups, and/or improve health and wellbeing in diverse clinical populations.

10.7 Limitations and future directions

Despite offering several novel contributions, the limitations of this research programme must also be acknowledged. Fundamentally, although the studies represented in this thesis move beyond self-reported assessments of emotion regulation, all three were cross sectional. It is therefore possible that unmeasured third variables may have contributed to, or been responsible for, the links between expressive regulatory skills and health outcomes. This limitation noted, performance-based paradigms bypass several of the issues regarding reporting biases and method-related covariation that undermine the findings from earlier studies. In addition, although steps were taken to control for potential confounds, including age, sex, and state emotion (Study 1), demographics and bio-behavioural risk factors (Study 2), and trait affect, loneliness, and effort (Study 3), it is nonetheless possible that unmeasured third variables such as state anxiety and/or motivational factors may be at least partly responsible for the observed links between skill and health.

Second, as with any cross sectional work, the direction of the relationship between expressive regulatory skill and physical health remains unclear. Prior work indicates that expressive flexibility prospectively predicts psychological adjustment (Bonanno et al., 2004; Galatzer-Levy et al., 2012; Levy-Gigi et al., 2016), indicating that such abilities may serve a protective function, buffering against daily stressors (Coifman & Bonanno, 2010; Gupta & Bonanno, 2011; Westphal et al., 2010), and the subsequent development of physical symptoms and disease states. However, it is also possible that poorer health reduces systemic resources available for the regulation of emotion, or changes performance motivations, and observed relationships may well be bidirectional. Longitudinal, prospective, and interventional studies, as well as work testing whether skills improve and/or decline across the course of disease progression or recovery would help to ascertain the direction of relationships. Doing so would clarify whether skill deficits increase the risk of poorer health outcomes and/or vice versa.

Third, each study took place in a controlled, laboratory environment, and whether skills assessed in the present studies reflect expressive regulatory skills as they are deployed in daily life is unknown. Interpersonal contexts generate numerous social and environmental cues, many of which may facilitate or interfere with expressive regulation. Furthermore, as there was no real ‘cost’ to regulatory failures in the paradigms used in this thesis, they may not be sufficiently naturalistic or motivating to capture maximal regulatory performance. In addressing this possibility, paradigms that incorporate personal and/or social costs and benefits of successful regulation might improve external validity.

Fourth, and related to the limitations inherent in laboratory paradigms, the ability to generate a genuine expression in a contrived setting is likely to reflect only one aspect of real world expressive skill. Other skills include sensitivity to context (Coifman & Bonanno, 2009), knowledge regarding the type and magnitude of expressivity that is appropriate to a given situation (Sheppes, Scheibe, Suri, & Gross, 2011; Sheppes et al., 2014), and the ability to express emotion in a manner that fits with social and cultural expectations (Adams, Hess, & Kleck, 2015; Consedine et al., 2014; Rychlowska et al., 2015). Future work using skill-based paradigms to test whether and how these diverse skills predict outcomes will lead to better understanding of the broader construct of emotion regulatory skill.

Finally, the relatively small, and homogenous samples used mean that findings should only cautiously be generalised beyond these groups. Study 1 was based on 117 men and women from across the lifespan, (men = 40%) and is reasonably representative, at least from an age perspective. Conversely however, in an effort to minimise the effects of age and gender on HRV and immunoregulatory molecules, Study 2 was comprised of 80 young women, and findings cannot be generalised to older adults, men, or clinical populations. It is also possible that inadequate variance in immune-parameters (Chapter 8) and HRV (Chapter 7) within this young, healthy sample made it difficult to detect effects, particularly since the links between emotion regulation and physical health may be more strongly evident in men (Chapter 9). Finally, although Study 3 was also based on men and women from across the lifespan, men made up only 25% of a predominantly white sample. Given that factors such as culture (Rychlowska et al., 2015), gender (Adams et al., 2015), and age (Malatesta & Izard, 1984; Tuck & Consedine, 2013) all influence the way in which people express emotions, future work using more diverse samples is needed before findings can be generalised.

10.8 Summary and concluding remarks

Despite limitations, the studies represented in this thesis have several notable strengths. Evidence that a diverse array of expressive skill-based metrics predicted outcomes, even when controlling for underlying trait emotion provides compelling evidence that the assessment of skills offers a useful way of investigating emotion regulation in the context of physical health. Moreover, findings that skills predicted self-reported health, objective physiological parameters, and clinically relevant disease risk metrics, demonstrates that the ability to flexibly regulate is associated with multiple domains of physical functioning. The fact that links to health were apparent across several skill-based operationalisations supports the possibility of a broad, expressive skill construct, and is consistent with theoretical and empirical work suggesting that the ability to implement a diverse repertoire of strategies is an appropriate way of thinking about healthy emotion regulation. Re-thinking emotion regulation in terms of abilities rather than traits should encourage theorists, clinicians and investigators to move away from the widely held, but problematic assumption that emotions should be expressed, suppressed, or regulated in a particular manner. Rather, it is increasingly apparent that successful regulation hinges on the *ability* to experience and express the most appropriate emotion in any given circumstance, where what is most appropriate is determined by personal goals and motivations.

Chapter 11 : Concluding remarks

The idea that emotion regulation has implications for physical health is not new. However, despite rapid growth, the study of emotion regulation is mired by the ongoing influence of early theory which views the suppression of emotion as dysfunctional. However, there are several reasons to question the idea that suppression is damaging to health. First, expressive suppression is only one part of a broader expressive regulatory construct, second, work investigating suppression is characterised by an over-reliance on self-reported, and/or trait metrics, and third, the idea that suppressing is damaging for health is at odds with theoretical accounts which argue that the ability to both enhance and suppress expressivity is necessary and beneficial.

In addressing these concerns, the concept of expressive flexibility has been gaining momentum in both the coping and emotion regulation literatures. Recent theoretical work suggests that healthy emotion regulation is characterised by the capacity to flexibly regulate emotion in response to challenges and opportunities in the environment. This view is consistent with functionalist, evolutionary, and developmental perspectives, which view the ability to regulate expressivity as a skill that has evolved to allow people to exert control over the sharing of information.

From this perspective then, the *ability* to flexibly adjust the outward expression of emotion in a manner that best fits with contextual demands should represent a useful index of adaptive emotion regulation. If flexibility is critical, self-reported traits that amalgamate regulatory strategy use across contexts and situations are an inadequate means of operationalising healthy emotion regulation. As such, a small, but consistent body of work has demonstrated that objectively assessed regulatory skills reliably predict indices of better psychological functioning, particularly in the context of trauma.

To this, the present program of doctoral study adds the first evidence that greater skill in regulating the outward expression of emotion is associated with better *physical* health outcomes. In demonstrating links between expressive regulatory skills and better subjective, physiological, and clinical health indices, the present findings are at odds with the suggestion that suppression is inherently unhealthy. Instead, they suggest that the ability to flexibly adjust expressive responding in a manner that fits with both personal goals and social demands may be a worthwhile means of conceptualising and measuring emotion regulation in the context of physical health. Such an approach has the potential to provide clearer targets for health-promoting interventions.

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