



## Physiological correlates of emotional reactivity and regulation in early adolescents



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### ABSTRACT

Few studies have examined physiological correlates of emotional reactivity and regulation in adolescents, despite the occurrence in this group of significant developmental changes in emotional functioning. The current study employed multiple physiological measures (i.e., startle-elicited eyeblink and ERP, skin conductance, facial EMG) to assess the emotional reactivity and regulation of 113 early adolescents in response to valenced images. Reactivity was measured while participants viewed images, and regulation was measured when they were asked to discontinue or maintain their emotional reactions to the images. Adolescent participants did not exhibit fear-potentiated startle blink. However, they did display affect-consistent zygomatic and corrugator activity during reactivity, as well as inhibition of some of these facial patterns during regulation. Skin conductance demonstrated arousal dependent activity during reactivity, and overall decreases during regulation. These findings suggest that early adolescents display reactivity to valenced pictures, but not to startle probes. Psychophysiological patterns during emotion regulation indicate additional effort and/or attention during the regulation process.

### 1. Introduction

Reactions to emotional stimuli, and the ability to regulate those reactions, are important to human functioning and are strong determinants of adaptive behavior across a range of domains, including mental health (Gross & Jazaieri, 2014), physical health (Isasi, Ostrovsky, & Wills, 2013), and school functioning (Schelble, Franks, & Miller, 2010). A common and important form of emotion regulation relates to the ability to effortfully change the expression and/or intensity associated with specific emotions (Gross & Jazaieri, 2014). Early adolescence is an especially important time to study this phenomenon, since it is a critical period for change in emotional reactivity and the emergence of affect regulation skills, especially related to increased ability to self-regulate (Riediger & Klipker, 2014), as well as a period of high risk for the onset of disorders of emotion (Allen & Sheeber, 2008). This suggests that understanding the processes associated with emotional reactivity and regulation in this age group will likely have important implications for affective, developmental,

and clinical science.

The psychobiological processes that underlie emotional reactivity and regulation in healthy adolescents are still not fully understood, despite much literature asserting the importance of these processes for emotional development during this phase of life (McLaughlin, Hatzenbuehler, Mennin, & Nolen-Hoeksema, 2011). However, there is some research addressing how this developmental stage differs from others. Compared to children, adolescents are better able to identify their emotions, deal proactively with emotional responses, and adapt emotion regulation strategies to diverse situations (Riediger & Klipker, 2014). Research on emotion regulation strategies suggests that adolescents use more proactive regulation strategies as they age, such as planful problem solving. An analysis of 58 studies on emotion regulation across the lifespan showed that adolescents are able to use both behavioral and cognitive regulation strategies (Zimmer-Gembeck & Skinner, 2011). There was also evidence from these studies that, although adolescence as a whole is a period of emotion regulation development, early adolescents may regress, demonstrating less

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effective emotion regulation and more intense reactivity to stress than in late childhood or late adolescence (Zimmer-Gembeck & Skinner, 2011).

Much of what we know about emotion regulation in adolescence comes from the research on cognitive control and self-regulation (Riediger & Klipker, 2014). Some literature suggests that the frontal brain regions associated with cognitive control are also activated during emotion regulation tasks (e.g., Mauss, Bunge, & Gross, 2007; Ochsner & Gross, 2005). One often-cited theory is that the imbalanced development of limbic and frontal brain areas during adolescence results in the emotional difficulties often observed during this developmental period. Once frontal brain areas catch up to the more 'emotional' limbic areas such as the amygdala, adolescents are better able to regulate their emotional responses (Casey, Jones, & Hare, 2008). It has also been theorized that the development of these frontal regions, and thus the ability to forecast and plan for the future, also contributes to difficulties in emotion regulation, partially due to the vast amount of new situations to which adolescents can now attend and form reactions (Pfeifer & Allen, 2012).

Despite the array of data on emotion reactivity and regulation in adolescents, no study to our knowledge has investigated these processes using psychophysiological measurements and paradigms. These include affective picture viewing paradigms that examine startle eyeblink modulation, facial muscle activity, skin conductance, and neurophysiological responses. These methods of assessment each yield different and complementary information, resulting in a richer understanding of emotional responses, as is detailed below. The addition of this information to the current knowledge on these processes in adolescence is an important next step in understanding emotional processes for this vulnerable age group. We will describe the common findings for each of these methods of assessment, and highlight studies that have utilized these methods with picture-viewing paradigms. This will be detailed first for emotional reactivity and later for emotional regulation.

### 1.1. Emotional reactivity

Startle eyeblink and facial muscle activity are both hypothesized to provide differing information dependent on the valence of the emotional stimuli being presented. The majority of findings from startle blink paradigms while viewing emotional stimuli corroborate the concept of *fear-potentiated startle*, which dictates that the startle blink is of the largest magnitude when viewing unpleasant stimuli (Bernat, Cadwallader, Seo, Vizuetta, & Patrick, 2011; McManis, Bradley, Berg, Cuthbert, & Lang, 2001). Fear-potentiated startle represents a learned, automatic response to fear-invoking stimuli, a learning process that is at least partially dependent on amygdala functioning (Klumpers, Morgan, Terburg, Stein, & van Honk, 2015). This finding is also present in more traditional fear paradigms, such as using threat or darkness (Balaban & Berg, 2008). Startle blink magnitude is commonly attenuated when viewing neutral and pleasant pictures (Bernat et al., 2011).

Affective facial muscle activity is commonly operationalized by measuring the *corrugator supercilii* ('frown') and *zygomaticus major* ('smiling') muscles. Research examining reactivity to valenced pictures typically yields a pattern one would expect – 'frown' muscles are more commonly activated when viewing unpleasant stimuli, while 'smile' muscles are activated when viewing stimuli that are pleasant (Bernat et al., 2011; Lang, Greenwald, Bradley, & Hamm, 1993).

Skin conductance and neurophysiological responses provide information on arousal levels of stimuli irrespective of their affective valence. In general, greater levels of skin conductance indicate higher levels of arousal, and are common when participants view either highly pleasant or unpleasant images, while neutral pictures elicit lower levels (Bernat et al., 2011; Gross, 1998). Neurophysiological responses measured via startle probe-elicited cortical event related potentials (ERPs) also commonly demonstrate lesser amplitude of the P300 ERP

component when viewing pleasant or unpleasant stimuli as compared to neutral stimuli (Bernat et al., 2011; Cuthbert, Schupp, Bradley, McManis, & Lang, 1998). The P300 component is believed to reflect the amount of attention paid to the startle stimulus (in this case, an auditory startle probe) when it is displayed secondary to an affective foreground stimulus (the goal-relevant stimulus; in this case, affective pictures). The implication is that paying more attention to the startle probe indicates that less attention is being paid to the competing cross-modal foreground stimulus.

These methods allow the interpretation of stimulus processing as it varies by valence and arousal. However, the majority of this information has come from adult studies. Research on the physiology of emotional reactivity in children gives a picture of how these methods might yield differing results in younger, still developing groups. In the only study we are aware of that has used multiple methods to assess affective reactivity in children, McManis et al. (2001) found greater skin conductance for seven- to ten-year-old girls than boys, especially when viewing unpleasant stimuli, and an increase in corrugator ('frown' muscle) activity for both genders when viewing unpleasant stimuli (with a greater increase for girls; McManis et al., 2001). Another common finding in this literature is that children do not display fear-potentiated startle in response to aversive stimuli (McManis et al., 2001; Van Brakel, Muris, & Derks, 2006), and a study on adolescents (mean age 16) also failed to observe this effect (Nederhof, Creemers, Huizink, Ormel, & Oldehinkel, 2011). However, there are notable exceptions to that pattern.

Despite a number of studies failing to observe fear-potentiated startle in younger samples, it should be noted that this effect has been demonstrated in certain studies (Quevedo, Smith, Donzella, Schunk, & Gunnar, 2010; Schmitz, Grillon, Avenevoli, Cui, & Merikangas, 2014). Of course there are a number of methodological differences between studies of affective startle modulation in younger samples that might explain these different findings. For example, studies have varied in terms of the age of participants (e.g., 3–9 in Quevedo et al., 2010 versus 16 in Nederhof et al., 2011) and the intensity of the startle probe (e.g., 95 dB in Van Brakel et al., 2006; McManis et al., 2001, and 105 dB in Waters, Lipp, & Spence, 2005).<sup>1</sup> However, these methodological variations do not appear to explain the presence or absence of fear-potentiated startle across these studies. The studies also differ in their specific stimulus paradigms. In particular, studies that employ picture viewing methods and present startle probes while viewing these images (whether affectively charged scenes or faces), tend not to find fear-potentiated startle in younger participants (McManis et al., 2001; Nederhof et al., 2011; Van Brakel et al., 2006). On the other hand, those studies that have observed fear-potentiated startle in youth used non-picture stimuli such as movie clips (Quevedo et al., 2010) or air blasts as the affective stimuli (Schmitz et al., 2014). Thus, it seems that paradigms that include more intense, threatening stimuli are more likely to yield findings of fear-potential in younger samples, despite the broader range of threatening stimuli that evokes this response in adults.

### 1.2. Emotional regulation

The measures described above have also been used to assess physiological markers of emotion regulation. In these studies participants are instructed to enhance or suppress their emotional reactions to stimuli, but the methods by which they do so are often self-determined. Thus, these studies do not directly assess cognitive emotion regulation strategies, such as those described by Gross (Gross, 1998) but rather examine the behavioral and physiological correlates of explicit efforts

<sup>1</sup> The study by Waters et al. (2005) did observe fear-potentiated startle for startle probes presented 60 ms following picture onset. Longer lead times that were similar to those examined in the other studies did not show evidence of affective startle modulation.

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