Emotion

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Incongruent Affect in Early Childhood: Neurobiological Markers and Links to Psychopathology

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Researchers have long investigated emotion-related facial expressions, such as smiling and frowning, to further the field's understanding of behavior, emotions, and psychopathology. Fewer studies have examined *incongruent affect*; facial expressions that do not match internal emotional experiences (e.g., smiling during frustration). Although not extensive, current accounts of incongruent affect in early childhood have assumed that these expressions indicate *masking*, an active regulatory process. Thus, many researchers contend that incongruent affect represents an adaptive emotion regulation strategy. However, little attention has been paid to incongruent affect, and its neurobiological correlates in early childhood. The present study examined complete versus partial incongruent smiling in preschool-aged children (3.5- to 5-years-old) who completed a frustration-eliciting task. We examined simultaneous neurobiological markers of incongruent smiles using functional near-infrared spectroscopy (fNIRS) and galvanic skin response (GSR) and tested links to parent-rated emotion regulation and psychopathology. Neutral and negative expressions were assessed as comparison expressions. Results revealed that complete incongruent smiling predicted poor effortful control, whereas partial incongruent smiling was not a significant predictor of regulation, neurobiological changes, or psychopathology. Neutral expressions predicted better effortful control skills and adaptive physiological response patterns. Results suggest that incongruent affect may signal poor regulation of positive affectivity in low-interpersonal contexts, while neutral expressions may act as masking expressions.

Keywords: incongruent affect, masking, emotion regulation, lateral prefrontal cortex (lPFC), galvanic skin response (GSR)

Young children's facial reactions to emotional stimuli have long been investigated by researchers to better understand early behavior, emotions, and psychopathology and interpreted by teachers and clinicians to inform education- and treatment-based decisions (Barrett et al., 2019; Cole, 1986; Cole et al., 1996; Frick et al., 2010; Liew et al., 2004). Most of the body of work to date examining facial reactions has focused on expected affect, such as frowning, and other anger expressions during negative emotional challenges (Barrett et al., 2019). Yet, some researchers and clinicians have commonly observed children, adolescents, and adults producing *incongruent affect*; expressions that do not match a person's covert emotional experience, particularly smiling during frustration and disappointment. Although incongruent affect reactions appear to occur from a very young age (Cole, 1986; Davis, 1995; Saarni, 1984), this behavior is grossly underresearched in early childhood. As a result, the developmental significance of early incongruent affect and what regulatory mechanisms it reflects are largely unknown. Due to the knowledge gap in the developmental and regulatory mechanisms of incongruent affect during the preschool years, the present study explicitly explored different types of smiling during frustration in preschoolers. This study further examined how these expressions predict neural and physiological responses to negative feedback, as well as psychopathology and self-regulation.

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Adrelys Mateo Santana served as lead for conceptualization, formal analysis, methodology, writing–original draft, and writing–review & editing, and contributed equally to project administration. Adam S. Grabell served as lead for funding acquisition, resources, and software and in a supporting role for conceptualization, formal analysis, methodology, writing–original draft, and writing–review & editing. Adrelys Mateo Santana and Adam S. Grabell contributed to project administration equally.

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Operationalization of Incongruent Affect

Ekman and Friesen (1982) first defined incongruent affect as facial muscle contractions producing a smile mixed with contractions producing fear, disgust, contempt, sadness, or anger. Specifically, in studies with adult populations, Ekman and Friesen (1982) defined incongruent affect as *false smiles* (e.g., genuine-looking smiles or smiles mixed with negative affect) within an uncomfortable or negative context. Other studies have more broadly defined incongruent affect in early childhood as smiling during a negative situation (Cole, 1986; Liew et al., 2004; Saarni, 1984). For instance, in a study examining spontaneous control of negative emotions in 3- to 9-year-old children, Cole (1986) defined incongruent affect as a lip corner pull and a cheek raise individually or combined, and a brow raiser, forming a genuine-looking smile. Similarly, studies examining incongruent affect in preschool- (e.g., 3- to 5-years-old) and elementary-aged children (e.g., 5- to 11-years-old) defined incongruent affect as the display of positive behaviors, such as smiling, laughing, and positive verbal gestures in a disappointing context (Davis, 1995; Liew et al., 2004; McDowell et al., 2000; Saarni, 1984). However, incongruent expressions are heterogeneous, and connections between incongruent affect, indicators of regulation, and psychopathology, may depend on the contraction of specific facial muscles (Ekman & Friesen, 1982). Incongruent expressions can be *complete* (e.g., smiling without co-occurring negative affect), the most common form of studying incongruent affect, or *partial* (e.g., smiling with co-occurring negative affect). To our knowledge, studies examining incongruent affect in early childhood have yet to explore whether children are more likely to exhibit complete or partial incongruent expressions when frustrated and how these expressions may differentially relate to emotion regulation (ER) and psychopathology.

Incongruent Affect in Early Childhood

The development of incongruent affect in early childhood has historically been debated among child development researchers. Ekman et al. (1980) suggested that young children cannot contract certain facial muscles, making it harder to display incongruent affect. Similarly, several studies suggested that young children struggle to conceal facial and vocal reactions when instructed to do so (DePaulo et al., 1982; Feldman et al., 1979). For instance, first graders were significantly less successful than seventh-graders and college students in using verbal and facial cues to deceive others (Feldman et al., 1979). Other studies, however, suggest incongruent affect is prevalent in early childhood (Cole, 1986; Davis, 1995; Liew et al., 2004; Saarni, 1984), such that children as young as 3 years of age can understand and exhibit incongruent affect when experiencing positive or negative emotions (Cole, 1986; Saarni, 1979). Notably, some researchers contend that displaying incongruent affect may depend on children's cognitive abilities and socialization development (Liew et al., 2004; Saarni, 1979). For instance, Saarni (1979) hypothesized that incongruent affect emerges with the development of complex cognitive functions, such as monitoring and rule acquisition, that materialize during the preschool years. Other researchers hypothesized that incongruent affect depends on the child's ability to understand social expectations (Liew et al., 2004), suggesting that incongruent affect develops as children's understanding of socialization increases. Incongruent affect may signal critical developmental processes in early childhood. However, the underpinning regulatory function of incongruent affect across various contexts remains largely unknown.

Contextualization and Regulatory Mechanisms of Incongruent Affect

Incongruent affect appears to be largely contingent on social context, as it often occurs when one experiences strong negative emotions (Ekman et al., 1988) and in uncomfortable situations with unfamiliar individuals (Cole, 1986). For instance, children who experienced disappointment in an unfamiliar social context accompanied by a stranger (e.g., the experimenter) smiled more than their counterparts who experienced disappointment in a non-social context (Cole, 1986). Therefore, it has been hypothesized that children display incongruent affect during a negative emotional challenge to conform to social norms (e.g., smiling to prevent discomfort for others), which may reflect adaptive ER (Cole, 1986; Saarni, 1984). Many researchers have interpreted children's smiling during frustration as *masking*, in other words, regulating their emotions by concealing negative affect (Cole et al., 1996; Davis, 1995; Liew et al., 2004; McDowell et al., 2000). However, while these findings suggest incongruent affect may be an ER strategy moderated by social context, as described below, further research is needed to understand their function in early childhood.

The scant research on early incongruent affect comes mostly from studies using highly interpersonal paradigms with strong social demands (e.g., Disappointing Gift Paradigm; Saarni, 1984) and has revealed regulatory and social patterns suggesting that incongruent affect indicates good ER and socially acceptable behavior. In a study examining the links between effortful control, low emotionality, social competence, adjustment, and display rule behaviors, Liew et al. (2004) used observational measures to code children's immediate affective (e.g., positive affect) and behavioral (e.g., negative remarks) reactions to a disappointing gift. A series of questionnaires were also used to assess effortful control, low emotionality, social competence, and participants' adjustment as rated by their parents, teachers, and peers. Results showed that children who made an incongruent expression (e.g., displayed positive affect) after receiving a disappointing gift were rated as having better effortful control, and were more well-adjusted and socially competent than their peers (Liew et al., 2004). While these results suggest that incongruent affect signals adaptive ER in early childhood, there remains a significant knowledge gap regarding the regulatory mechanisms occurring during incongruent affect. For example, it is unclear whether smiling during a negative emotional challenge always represents an active regulatory mechanism, such as *masking*, instead of maladaptive regulatory and temperamental patterns.

Indeed, researchers have also linked high and intense displays of positive affect to externalizing, conduct, and disruptive behaviors (Cole et al., 1994; Eisenberg et al., 1996; Fowles, 1987; Rydell et al., 2003), raising the possibility that smiling during frustration may be, in some cases, a potential risk factor. In a study examining the links between emotionality, ER, and behavioral adaptation in school-age children (e.g., 5- to 8-years-old), Rydell et al. (2003) found high positive emotionality-exuberance and low regulation of positive affect were associated with externalizing behaviors. The same study found that low regulation of positive emotions and exuberance was further associated with low levels of prosocial behavior. Another study examining the relations of emotionality and regulation in elementary school children similarly found a link between high positive emotionality and teacher- and father-rated conduct problems (Eisenberg et al., 1996). These studies suggest that smiling could reflect completely divergent underlying processes that may be difficult to tease apart from overt behavior alone. Multimethod approaches, such as combining neural and physiological changes during facial expressions, may elucidate when incongruent affect may signal regulation and when it may be maladaptive.

Neural and Physiological Correlates of Incongruent Affect

A multimodal investigation of the early regulatory mechanics of incongruent affect requires devices that are sensitive to stress arousal and regulation and that are tolerable to young children. Galvanic skin response (GSR), an accessible and sensitive measurement of changes in electrodermal activity driven by the autonomic nervous system, is an ideal measure of emotion-related physiology. GSR has historically been used in emotion reactivity research, as GSR changes during emotional challenges signal stimuli-related reactivity and involve ER processes (Boucsein, 2012; Cacioppo & Sandman, 1978; Cole et al., 1996; Kadziolka et al., 2016). If smiling during frustration were an active regulatory process (e.g., masking), one might expect increases in GSR during the frustration stimuli, suggesting onset of emotion-related stress, followed by a decrease in GSR, suggesting modulation of that stress. Alternatively, hypo- or hyperresponsiveness to the frustration stimuli, as measured by changes in GSR, followed by a lack of return to physiological baseline, may indicate a less adaptive response, as many studies have found hypo- and hyperresponsive patterns of physiological activation to be associated with maladaptive behaviors and poor ER strategies (Beauchaine et al., 2007; Boyce et al., 2001; Calkins & Dedmon, 2000; Cole et al., 1996). To our knowledge, no one has linked smiling during frustration with simultaneous changes in GSR.

Moreover, if smiling during frustration is a form of active regulation, physiological changes associated with incongruent affect would be driven by neural regions implicated in the top-down regulation of negative emotions, notably the lateral prefrontal cortex (lPFC; Goldin et al., 2008; Kim & Hamann, 2007; Silvers et al., 2015). Recent studies using functional near-infrared spectroscopy (fNIRS) suggest ER-related lPFC activation is present in early childhood (Grabell et al., 2019; Perlman et al., 2014). Thus, examining whether smiling during frustration is associated with strong versus weak concurrent lPFC activation may elucidate whether the expression signals regulation or a maladaptive process, such as poor regulation of positive affect in early childhood.

Smiling and Psychopathology

How smiling during frustration indicates adaptive regulation has important implications for identifying the most common forms of early psychopathology, particularly early externalizing problems and irritability. Irritability is a transdiagnostic symptom that comprises anger, annoyance, and temper tantrums (Stringaris et al., 2018; Wakschlag et al., 2018) present in over a dozen *Diagnostic and Statistical Manual of Mental Disorders-Fifth Edition* (*DSM–5*) disorders and the most common cause of psychological services referrals in early childhood (Stringaris et al., 2018). Externalizing behavior problems comprise aggressive and defiant behaviors that violate social norms and are often a symptom of conduct disorder in early childhood (Bongers et al., 2003; Rothbaum & Weisz, 1994). Associations between facial expressions and early psychopathological disorders have demonstrated significant clinical utility. For instance, the frequency of negative expressions children exhibited was significantly positively associated with parent-rated irritability and externalizing problems in young children and differentiated children above and below clinical cutoffs (Grabell et al., 2020). Notably, smiling during frustration differentiated between clinical and nonclinical irritability with fair clinical utility, such that *more* smiling during frustration onset increased the risk for clinically significant irritability (Grabell et al., 2020), which is counter to the contention that this expression reflects adaptive ER.

The Present Study

The present study explored preschool-age children's complete and partial incongruent smiling during frustration and how these expressions predicted simultaneous neural and physiological changes and parent-reported psychopathology and self-regulation. Young children ages 3.5- to 5-years-old completed an emotion-eliciting computer task during which they received predetermined positive and negative feedback. The present study focused on the negative feedback condition, as hypotheses were specific to children's facial responses to frustration. Children's facial expressions were videotaped while lPFC activation via fNIRS and physiological response via GSR were recorded simultaneously. The Facial Action Coding System (FACS) was used to identify the frequency of partial and complete incongruent smiling during frustration onset (e.g., while receiving negative feedback). Here, "incongruent" specifically refers to incongruence between the child's overt affective expression (i.e., smiling) and the emotion the task trial was designed to elicit (i.e., frustration). Caregivers reported their child's self-regulation, externalizing problems, and irritability. We hypothesized that children would produce complete and partial incongruent smiling and explored whether complete or partial incongruent smiling was more frequent. We further hypothesized that a higher frequency of smiling during frustration would predict better self-regulation, greater lPFC activation, modulated physiological reactivity, a robust return to physiological baseline (recovery), and lower irritability and externalizing behavior. We also examined and compared neutral and negative expressions to determine whether the effects were explicitly due to incongruent affect as opposed to overall expressivity.

Method

Participants

The present study was part of a larger project assessing behavioral, neural, and physiological predictors of irritability in early childhood. Ninety-six children, ages 3.-5 to 5-years-old ($M_{\text{age}} = 4.58$, $SD = .75$;

53.1% male, 46.9% female; 75% White, 9.8% Black or African American, 9.8% Multiracial, 2.2% Asian, 3.3% chose not to answer; 16.7% also identified as Latinx), participated. Participants were recruited via social media platforms and community outreach. Exclusionary criteria included psychotic symptoms, developmental or intellectual disability diagnosis, history of head trauma with loss of consciousness, and inability to speak or understand English.

Sample size was determined before data collection based on pilot study power analyses and previous work using a similar framework (Grabell et al., 2019). Eight children had missing facial expression data due to poor video quality and incomplete processing and coding. Eight children also had missing GSR data due to uneditable noise in the signals and children choosing not to wear the electrodes. Similarly, four children had missing neural data due to poor signals and participants choosing not to wear the fNIRS cap. Final analyses were completed with the maximum number of participants available for each analysis type. Parents were briefed and provided informed consent at the beginning of the study. Families received a $60 compensation for participating, and children received a certificate and a small toy. This research study was approved by the University's Institutional Review Board (IRB).

Emotion Eliciting Task

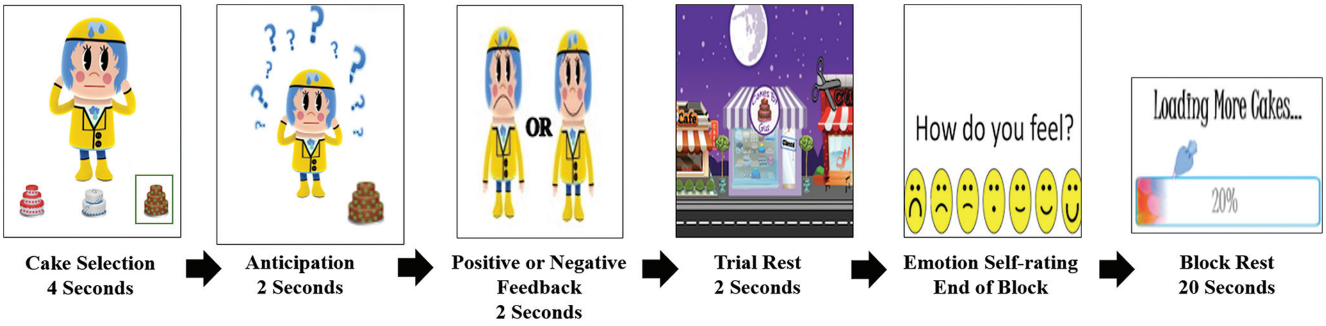
Children played the emotion-eliciting task "Incredible Cake Kids" (ICK; Grabell et al., 2019) on a touchscreen computer, while lPFC activation via fNIRS, and physiological responses via GSR, were simultaneously recorded (description below). The task consisted of a virtual bakery that required the child's help choosing cakes for customers. Children first watched an instructional video and practiced playing the game, during which the researcher told them the task was skill-based and to select the "most delicious cake," as their performance would be evaluated. Following the practice round, children completed 30 trials of the task. Each trial presented a virtual customer and three virtual cakes that remained on the screen for 4 s, followed by 2 s of "anticipation" and 2 s of positive (e.g., "yummy") or negative (e.g., "yuck") feedback, and a 2-s rest period. Unbeknownst to the child, positive and negative feedback were predetermined. The task was subdivided into three positive (e.g., four positive and one negative feedback trial) and three negative (e.g., four negative and one positive feedback trial) blocks, with 20-s rest periods between blocks and a 7-point emotion self-rating scale at the end of each block (see Figure 1). The task lasted approximately 10 min and was video recorded via high-definition cameras. The experimenter stayed out of the child's field of view, ensuring that the child focused on the task.

ICK was modeled after commonly used frustration paradigms in older children, which induce frustration by providing predetermined and frequent negative feedback (Deveney et al., 2019; Grabell et al., 2019). Previous studies using this type of feedback procedure have found it to effectively elicit frustration in preschoolers (Camacho et al., 2021; Grabell et al., 2019, 2017; Perlman et al., 2015), and are compatible with simultaneous neural and physiological recording. To further ensure that frustration was caused by the unexpected negative feedback, every customer and cake design was different. Although the task included positive and negative trials, only negative trials were examined because our research questions were specific to frustration (e.g., negative feedback). Moreover, participants' emotional self-ratings results are not reported, as previous work using ICK has found this data to be unreliable (Grabell et al., 2019, 2017). In addition, previous work has found that young children tend to choose the most extreme states when presented with Likert scales, and often struggle to reliably report their own emotions (Zeman et al., 2007).

Lateral Prefrontal Cortex Activation Measurement

Children's lateral prefrontal cortex activation was recorded via functional near-infrared spectroscopy (fNIRS), a noninvasive optical imaging system (NIRx Medical Technologies, Orlando, FL). fNIRS is well-suited for infants and young children and is more robust to motion artifacts than traditional neuroimaging technology (e.g., functional magnetic resonance imaging [fMRI] and electroencephalogram [EEG]), allowing children to move comfortably and making it easier to record simultaneous neural activation and facial expressions (Wilcox & Biondi, 2015). The fNIRS probe contained eight light-source emitters with 760 nm and 850 nm LED lights and four detectors. Sources and detectors were attached to an elastic cap at an average distance of 3 cm. We followed the 10–20 international coordinates to position the probe. We also aligned the interior medial corner of the probe with FpZ and expanded it over Brodmann areas 10 (ventrolateral prefrontal

Figure 1
Incredible Cake Kids Task Trial



Note. See the online article for the color version of this figure.

cortex) and 46 (dorsolateral prefrontal cortex) on the right and left hemispheres.

Analyses were conducted using the NIRS Brain AnalyzIR Toolbox (Santosa et al., 2018). Data were collected at 7.81 Hz and down-sampled to 4 Hz. Changes in light saturation were converted to optical density and then changed in oxy- and deoxyhemoglobin estimates via the modified Beer-Lambert Law (Swinehart, 1962). A general linear model was used to assess the contrast between frustration blocks minus rest blocks at the subject level with an auto-regressive whitened, weighted least-squares (AR-iRLS) model used to reduce the effects of motion artifacts and systemic physiology (Barker et al., 2013). To minimize family wise error, the 10 source-detector pair channels were averaged into two regions of interest corresponding to the left and right lPFC. Averaging the pair channels into the left and right lPFC also provides information about laterality, consistent with other fNIRS studies on preschool samples (Grabell et al., 2019; Li et al., 2017; Tsujii et al., 2010). Subject-level activation estimates for each ROI were exported to be imputed into regression models.

Physiological Activity Measure

Children’s GSR was measured via MindWare (Gahanna, OH) BioNex chassis disposable GSR electrodes, which were placed in the palms of the nondominant hand to minimize motion artifacts. Following data collection, GSR data was processed via MindWare proprietary electrodermal activity (EDA) analysis software. We first processed and edited any skin conductance responses (SCRs) artifacts (e.g., motion or respiration artifact) in time mode. Segments were edited when they exhibited SCRs with an amplitude below two microsiemens (uS), as a normal uS amplitude ranges from .5 to 45 uS (Morgan, 2017) or when the respiration was not consistent with the SCRs. All segments were written in time mode, irrespective of the quality or percentage edited. We also processed and wrote the GSR data in event mode; however, we did not write any segments that had 50% or higher edited, as these were our segments of interest. For this study, we only used the segments written in event mode. We exported the number of SCRs for each frustration, reward, and rest block. We converted SCR scores to SCR rate per second as frustration and reward blocks could vary in length depending on the child’s responding pattern. Baseline SCRs were collected during the 20-s rest periods in between blocks. We created changed scores between rest blocks and subsequent frustration blocks and averaged them as a measure of physiological *reactivity*. We also created changed scores between frustration blocks and subsequent rest blocks and averaged them as a measure of physiological *recovery*. Note that to compute *reactivity*, the rest block before the frustration block was used, and to compute *recovery*, the rest block that occurred after the frustration block was used.

Facial Expressions Coding

Children’s facial expressions were video recorded via two high-definition cameras, one trained on the child’s face and another at an angle. ELAN (Version 6.0, computer software; ELAN, 2020) was used to divide the videos into positive and negative blocks, which permitted coders to denote the facial expression codes for each 2-s feedback window. The feedback type was hidden in the video file, and the videos were muted during coding to reduce coder bias.

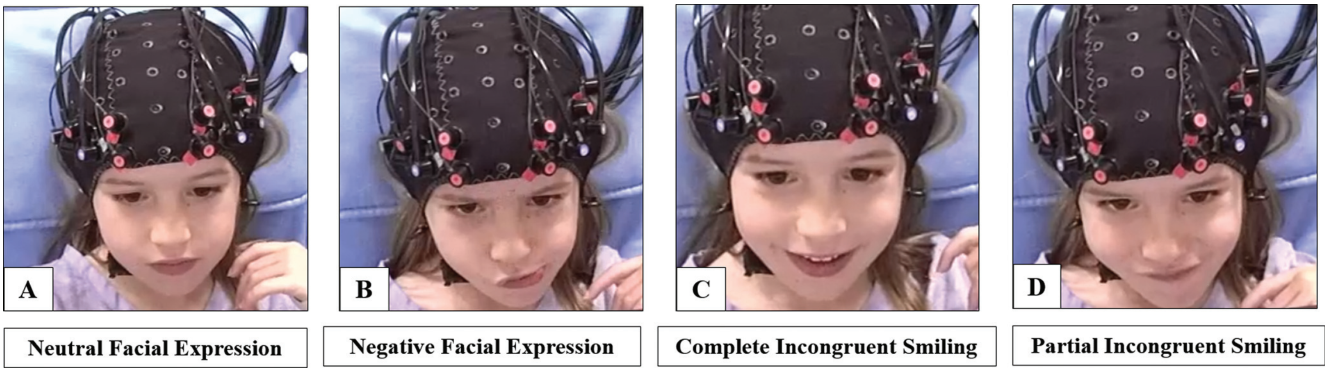
Ekman and Friesen (1978) FACS was used to code children’s facial expressions. FACS is an anatomically based system that uses individual facial muscle movements denoted as action units (AUs). In the present study, the following subset of AUs were coded: brow lowerer (AU 4), nose wrinkler (AU 9), upper lip raiser (AU 10), lip corner puller (AU 12), and lip corner depressor (AU 15). AUs 9 and 10 were combined and coded as a single unit (e.g., 9/10). Code selection was informed by previous literature on children’s facial expressions (Grabell et al., 2018, 2020) and AUs observed during pilot coding. Before coding in the laboratory, coders completed rigorous FACS training, passed the FACS certification test, and completed a lab-based FACS training specific to coding children. Each team of coders achieved interrater reliability of .8 or higher during in-lab training before FACS coding. Coders were assigned individual, randomized blocks across participants to ensure they could not discern the timing of each type of feedback throughout the task. To prevent coders’ preexisting knowledge of the child’s temperament, coders were not assigned participants with whom they had prior interaction (e.g., present during study protocol or transcribed their video). Coders were instructed to code the AUs present within a 4-s segment (e.g., 2 s of feedback and two additional seconds), irrespective of the duration and intensity of the expression. Lastly, we coded for visibility to account for obstructions of part of the face or the entire face. Visibility codes included: Brows and forehead not visible (AU 70), eyes not visible (AU 71), lower face not visible (AU 72), entire face not visible (AU 73), and unscorable (AU 74).

Every block was double-coded by two independent coders. After coding, the two independent coders went over both codes, resolved disagreements, added any initially missed codes, and removed any codes that coders agreed were not present to create a consensus code, which was used in analyses. However, interrater reliability was calculated as the agreement between their individual codes using the formula provided by the official FACS manual (e.g., number of codes agreed upon divided by the number of total codes × 2). The overall reliability of the present study was acceptable ($\alpha = .72$).

The frequency of four mutually exclusive facial expressions during negative feedback was calculated: complete incongruent smiling, partial incongruent smiling, neutral expressions, and negative expressions. Complete incongruent smiling was defined as a lip corner puller (AU 12) during negative feedback. Partial incongruent smiling was defined as the presence of a brow lowerer (AU 4), nose wrinkler (AU 9), upper lip raiser (AU 10), or lip corner depressor (AU 15) co-occurring with a lip corner puller (AU 12). Neutral expressions were defined as the lack of facial expressions during negative feedback. Negative expressions were defined as the presence of a brow lowerer (AU 4), nose wrinkler (AU 9), upper lip raiser (AU 10), or lip corner depressor (AU 15) without any co-occurring lip corner puller (AU 12; see Figure 2). The percentage of facial expression was calculated by coding the frequency of expression occurrence and dividing it by the number of frustration trials (e.g., 15 negative feedback trials). In the present study, incongruent smiling was operationalized as smiles that specifically occurred during the negative trials.

Figure 2

Participant Making Four Types of Facial Expressions



Note. A child participant producing a neutral facial expression (A), a negative expression denoted by the brows lowering towards each other (AU4) and the contraction of the upper lip raiser (AU10), producing a sneer and deepening the smile line (B), a complete incongruent smiling expression denoted by the contraction of the lip corners puller (AU12), producing a smile (C), and a partial incongruent smiling expression denoted by the contraction of the lip corners puller (AU12) and the upper lip raiser (AU10), producing a smile with traces of frustration (D). The child's legal guardian signed a Photo Release form, granting permission to use the participant's photos for internet and print advertisement and scientific purposes. AU = action units. See the online article for the color version of this figure.

Self-Regulation and Psychopathology Measures

Self-Regulation

Caregivers reported their children's self-regulation using the Effortful Control subscale of the Child Behavior Questionnaire (CBQ; Rothbart et al., 2001). The CBQ comprises 94 items, divided into subsets, and then averaged to create 15 subscales. Effortful control is calculated by averaging the Attentional Focusing (six items, $\alpha = .77$), Inhibitory Control (six items, $\alpha = .66$), Low-intensity Pleasure (eight items, $\alpha = .68$), and the Perceptual Sensitivity (six items, $\alpha = .70$) subscales of the CBQ. All subscales use a 7-point Likert scale, 1 = *extremely untrue* and 7 = *extremely true*. The CBQ has been demonstrated to be a valid and reliable measure of parent-reported child temperament (Putnam & Rothbart, 2006).

Externalizing

Caregivers reported their child's Externalizing and Internalizing problems via the Child Behavior Checklist (CBCL; Achenbach & Rescorla, 2000). The CBCL comprised 99 items, and parents rated the extent to which each behavior was true of their child in the present or within the past 2 months via a 3-point Likert scale (e.g., 0 = *not true*, 1 = *somewhat or sometimes true*, and 2 = *very true or often true*). The present study focused on examining the externalizing problems composite (e.g., "Gets in many fights"). The externalizing problems composite is measured by adding the Attention Problems (five items, $\alpha = .78$) and Aggressive Behavior (19 items, $\alpha = .94$) subscales of the CBCL.

Irritability

Caregivers also reported their child's temper modulation via the Multidimensional Assessment of Preschool Disruptive Behavior (MAP-DB; Wakschlag et al., 2012). The MAP-DB comprises 111 items, subdivided into four dimensions; Temper Loss (22 items, $\alpha = .97$), Noncompliance (22 items, $\alpha = .96$), Aggression (25 items, $\alpha = .96$), and Low Concern for others (nine items, $\alpha = .94$). Parents rated how often their child engaged in each behavior weekly via a 6-point Likert scale (e.g., 0 = *never*, 1 = *rarely (less than once a week)*, 2 = *some (1–3 days)*, 3 = *most (4–6 days)*, 4 = *every day of the week*, 5 = *many times each day*). The present study examined the Temper Loss dimension of the MAP-DB to measure irritability (e.g., In the past month, how often did your child act irritable?). All self-regulation measures were processed and analyzed as continuous variables.

Analysis Strategy

Paired-samples *t* tests were used to examine differences among the four facial expressions during the frustration trials. Following previous literature using the ICK task, a paired-samples *t* test of negative expressions across conditions (e.g., positive and negative trials) was performed as a validity test of the task probing frustration. Preliminary descriptive statistics were then performed to test for univariate and multivariate outliers. We then completed a series of multiple linear regressions to test whether a higher frequency of incongruent affect during frustration was associated with better self-regulation, greater lPFC activation, modulated physiological reactivity, robust physiological recovery, and lower behavioral problems. Lastly, a False Discovery Rate (FDR) correction was performed to correct for multiple comparisons. All analyses were performed via IBM SPSS Statistics 24 (IBM SPSS Statistics for Windows, Version 24.0; IBM Corp., 2016).

Transparency and Openness

The present study reports screening, exclusionary criteria, a complete description of data analysis, data exclusion due to outliers, and all measures used. Data, analysis codes, and other research materials obtained during the present study are not available via a repository, as most of our data contains sensitive and identifiable information (e.g., neural, physiological, and behavioral recordings of participants), which cannot be published for public access. However, all data, analysis codes, and other study materials are available upon request for research purposes. The current study design and analysis strategy were not preregistered; however, research questions, hypotheses, and analysis strategies were formulated before data analysis.

Results

Preliminary Analyses

Descriptive statistics and correlations for all variables can be found in Table 1. On average, preschool children's exhibition of partial incongruent smiling ranged from .00–.93 (*M* = .12, *SD* = .18), complete incongruent smiling ranged from .00–1.00 (*M* = .46, *SD* = .29), neutral expressions ranged from .00–.93 (*M* = .31, *SD* = .25), and negative expressions ranged from .00–.60 (*M* = .04, *SD* = .09) during frustration trials. A paired-sample *t* test revealed that preschool children generated significantly more complete incongruent smiling (*M* = .46, *SD* = .29), than partial incongruent smiling (*M* = .12, *SD* = .18, $t(76) = 11.43$, $p < .001$), neutral expressions (*M* = .31, *SD* = .25, $t(76) = 2.65$, $p = .01$), and negative expressions (*M* = .04, *SD* = .09, $t(76) = 11.74$, $p < .001$). Children generated significantly more neutral expressions (*M* = .31, *SD* = .25) than partial incongruent smiling (*M* = .12, *SD* = .18, $t(76) = 3.61$, $p = .001$) and negative expressions (*M* = .04, *SD* = .09, $t(76) = 9.26$, $p < .001$), and significantly more partial incongruent smiling (*M* = .12, *SD* = .18) than negative expressions (*M* = .04, *SD* = .09, $t(76) = 9.26$, $p = .001$). Bivariate correlations showed that all facial expressions were, in general, strongly correlated with each other. Neutral expressions, however, were inversely correlated with complete and partial incongruent smiling. Bivariate correlations and independent-samples *t* tests showed that facial expressions were unrelated to age and gender ($p > .10$), thus age and gender were not controlled for in subsequent analyses.

Next, a paired-samples *t* test of negative expressions across conditions (e.g., positive and negative trials) was performed as a validity check that children produced more negative affect during frustration blocks than winning blocks, and that the task induced mild to moderate frustration. The test revealed that children displayed negative affectivity significantly more following frustration onset (*M* = .04, *SD* = .09), than following positive feedback (*M* = .01, *SD* = .04, $t(76) = 2.54$, $p = .01$). In addition, we found that 29% of children made at least one purely negative face, and 65% of children made at least one face that was a mix of smiling and negative affect during frustration blocks. This suggests that, on average, the negative trials probed the intended mild to moderate frustration, whereas the positive trials, on average, elicited other types of facial expressions.

Lastly, preliminary descriptives revealed three extreme univariate outliers who produced more facial expressions than peers and were more than three standard deviations above the mean. A Mahalanobis distance test further showed that two univariate outliers were also statistically significant multivariate outliers for every individual facial expression and outcome variable at $p < .001$. Results described below were similar with and without the outliers. Some results were significant at the $p < .10$ threshold with

Table 1
Descriptive Statistics and Correlations Across Variables

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Complete incongruent smiling	—										
2. Partial incongruent smiling	.37**	—									
3. Negative expressions	−.09	.37**	—								
4. Neutral expressions	−.64**	−.30**	.04	—							
5. Effortful control	−.24*	−.12	−.04	.29*	—						
6. Externalizing	.19	.001	.05	−.07	−.44**	—					
7. Irritability	.16	−.02	−.01	−.03	−.35**	.79**	—				
8. Left lPFC	−.04	.21	.15	.06	.08	.04	.08	—			
9. Right lPFC	−.17	.10	.18	.01	−.01	.04	−.12	.40**	—		
10. GSR reactivity	−.23	−.17	−.03	.36**	.34**	.08	.18	.13	.13	—	
11. GSR recovery	.20	−.05	−.05	−.24	−.28*	.03	.06	−.25*	−.27*	−.65**	—
N	77	77	77	78	83	84	86	82	82	77	77
M	0.46	0.12	0.04	0.31	5.07	51.87	36.42	−6.05	−5.54	0.07	−0.06
SD	0.29	0.18	0.09	0.25	0.69	12.99	20.88	20.00	18.52	0.06	0.08
Range	.00−1	.00−.93	.00−.60	.00−.93	3−6.21	28−83	4−95	−59.43−66.75	−76.22−35.13	−.18−.25	−.22−.18

Note. lPFC = lateral prefrontal cortex; GSR = galvanic skin response. Correlation results exclude three univariate and multivariate outliers.
* $p < .05$. ** $p < .01$.

the outliers included and significant at the $p < .05$ threshold with the outliers removed. Results are presented with outliers removed; however, we denote below which results shifted within or outside the $p < .05$ threshold had outliers been included.

Linear Regression Analyses

Multiple linear regression models were conducted to test the hypothesis that a higher frequency of incongruent affect during frustration would predict better self-regulation, greater lPFC activation, moderated physiological reactivity, robust physiological recovery, and lower behavioral problems and irritability. Because predictor variables were significantly correlated with each other and to be consistent with initial hypotheses, individual regression models were conducted. As expected, multiple linear regressions revealed medium effect-sized results. Although our sample size was robust compared with other preschool neuroimaging studies, a sample size under 80 increases the risk of a Type II error. Thus, to balance the risk of Type I and Type II errors (Wasserstein & Lazar, 2016), we report both uncorrected, and FDR corrected p values. Lastly, we further explored whether the four distinct facial expressions uniquely predicted the outcomes as a form of comparison. However, as expected, entering all predictors in the same model increased the standard errors, making effects more difficult to detect (see Appendix A Table A1).

Contrary to hypothesis, higher complete incongruent smiling predicted worse effortful control ($b = -.04$, $SE = .02$, $R^2 = .06$, $p = .04$, $p_{\text{Adjusted}} = .37$). When outliers were included, complete incongruent smiling did not significantly predict effortful control ($b = -.03$, $SE = .02$, $R^2 = .05$, $p = .07$). Complete incongruent smiling did not significantly predict externalizing behaviors, irritability, neural activation, or GSR reactivity and recovery levels ($p >$ .06). Similarly, partial incongruent smiling did not significantly predict effortful control, externalizing behaviors, irritability, neural activation, or GSR reactivity and recovery ($p > .07$). Negative expressions also did not significantly predict effortful control, externalizing behaviors, irritability, neural activation, or GSR reactivity and recovery ($p > .14$). When outliers were included, negative expressions became a significant predictor of right lPFC activation ($b = 3.51$, $SE = 1.63$, $R^2 = .06$, $p = .04$). Lastly, neutral expressions significantly, positively predicted effortful control ($b =$ .05, $SE = .02$, $R^2 = .08$, $p = .01$, $p_{\text{Adjusted}} = .14$), such that more frequent neutral expressions predicted better effortful control skills. Neutral expressions also predicted higher GSR reactivity ($b =$ .006, $SE = .002$, $R^2 = .13$, $p = .003$, $p_{\text{Adjusted}} = .08$), such that more frequent neutral expressions predicted higher physiological responses. Furthermore, neutral expressions significantly predicted higher GSR recovery ($b = -.005$, $SE = .002$, $R^2 = .06$, $p =$ .05, $p_{\text{Adjusted}} = .20$), such that more frequent neutral expressions predicted a more robust return to physiological baseline when frustration was over. Neutral expressions did not significantly predict externalizing behaviors, irritability, and neural activation ($p >$ .55). See Table 2 for all regression outcomes with effect sizes.

Discussion

The present study aimed to understand the developmental significance of incongruent expressions in early childhood, specifically smiling during frustration, by examining their neural and physiological correlates and relation to self-regulation and psychopathology. Negative and neutral expressions were also examined to determine whether the effects were related to incongruent affect instead of overall expressivity. We found that children made complete and partial incongruent smiling during frustration, with complete incongruent smiling being significantly more common. Contrary to our hypotheses, complete incongruent smiling, but not partial incongruent smiling, predicted worse effortful control. Neutral expressions predicted better effortful control and increased GSR reactivity followed by a robust recovery. All other models were not statistically significant.

Complete Incongruent Smiling

Results suggest that young children's smiling during a negative event is potentially more complicated than what has been reported in the extant literature. Some researchers had previously concluded that incongruent affect indicates masking, implying an active regulatory process (Cole et al., 1996; Davis, 1995; Liew et al., 2004; McDowell et al., 2000). However, the present findings suggest that whether incongruent affect reflects active masking may depend on the facial muscles contracted in the expression and the social context in which it occurs. In the present study, complete incongruent smiling indicated deficient temperamental effortful control, suggesting that smiling without leakage of negative affect during an emotional challenge is not always adaptive or indicates masking, contrasting previous work (Liew et al., 2004; McDowell et al., 2000). Complete incongruent smiling in the present study may instead be indicating high positive affectivity or capturing children high in temperamental exuberance, which have been previously linked to poor ER skills and externalizing, conduct, and disruptive behaviors (Cole et al., 1994; Eisenberg et al., 1996; Fowles, 1987; Rydell et al., 2003).

The present findings further highlight the potentially crucial role of social context in interpreting whether incongruent affect is adaptive or maladaptive. Prior work on early incongruent affect used Saarni's (1984) disappointing gift paradigm, a highly interpersonal task in which children receive a disappointing gift directly from a stranger (e.g., the researcher), naturally eliciting display rule behaviors (e.g., showing gratitude despite one disliking the present). As a result, children who display incongruent affect within the disappointing gift paradigm context are thought to be masking and perceived as adaptive and socially competent (Liew et al., 2004; McDowell et al., 2000). In contrast, the paradigm used in the present study was much less interpersonal and more similar to real-world, goal-focused, frustration scenarios such as a child working on a challenging puzzle, game, or toy. It is, therefore, necessary to consider mild versus high interpersonal context when examining incongruent affect, as the social context may indicate vastly different interpretations of this behavior. For instance, if complete incongruent smiling occurs in a low to moderate interpersonal context, it may be indicating poor modulation of positive affectivity or even capturing children high in temperamental exuberance. In contrast, the same behavior in an interpersonal context may indicate an adaptive regulation strategy driven by expected social norms. Future work should further examine complete incongruent smiling across social and nonsocial contexts to determine how context moderates the function of complete incongruent smiling in early childhood.

Table 2
Multiple Linear Regression Effects Across Four Facial Expressions

Model	*B*	*SE*	95% CI [LL, UL]	β	*F*	*df*	*p*	p_{Adjusted}
Complete incongruent smiling[a]								
Effortful control[b]	−0.04	0.02	[−0.08, −0.002]	−0.24	4.42	1, 71	.04*	.37
Externalizing[b]	0.61	0.36	[−0.11, 1.33]	0.19	2.81	1, 72	.10	.40
Irritability[b]	0.78	0.58	[−0.38, 1.94]	0.16	1.80	1, 72	.18	.42
Left lPFC[b]	−0.21	0.60	[−1.40, 0.98]	−0.04	0.12	1, 69	.73	.97
Right lPFC[b]	−0.76	0.52	[−1.79, 0.27]	−0.17	2.15	1, 69	.15	.42
GSR reactivity[b]	−0.003	0.002	[−0.007, < .001]	−0.23	3.57	1, 65	.06	.34
GSR recovery[b]	0.004	0.002	[−0.001, 0.01]	0.20	2.70	1, 65	.11	.39
Partial incongruent smiling[a]								
Effortful control[b]	−0.03	0.03	[−0.10, 0.03]	−0.12	1.03	1, 71	.31	.62
Externalizing[b]	0.003	0.67	[−1.33, 1.33]	0.001	<0.001	1, 72	.10	.97
Irritability[b]	−0.21	1.07	[−2.34, 1.91]	−0.02	0.04	1, 72	.84	.98
Left lPFC[b]	1.88	1.03	[−0.18, 3.94]	0.21	3.30	1, 69	.07	.33
Right lPFC[b]	0.75	0.93	[−1.10, 2.61]	0.10	0.66	1, 69	.42	.78
GSR reactivity[b]	−0.004	0.003	[−0.01, 0.002]	−0.17	1.95	1, 65	.17	.43
GSR recovery[b]	−0.002	0.004	[−0.01, 0.01]	−0.05	0.17	1, 65	.69	1.07
Negative expressions[a]								
Effortful control[b]	−0.04	0.12	[−0.28, 0.20]	−0.04	0.12	1, 71	.74	.94
Externalizing[b]	0.91	2.32	[−3.71, 5.53]	0.05	0.15	1, 72	.70	1.03
Irritability[b]	−0.43	3.70	[−7.81, 6.94]	−0.01	0.01	1, 72	.91	.94
Left lPFC[b]	4.43	3.64	[−2.83, 11.68]	0.15	1.48	1, 69	.23	.50
Right lPFC[b]	4.76	3.19	[−1.61, 11.12]	0.18	2.22	1, 69	.14	.43
GSR reactivity[b]	−0.002	0.01	[−0.03, 0.02]	−0.03	0.04	1, 65	.84	.94
GSR recovery[b]	−0.005	0.01	[−0.03, 0.02]	−0.05	0.14	1, 65	.71	.99
Neutral expressions[a]								
Effortful control[b]	0.05	0.02	[0.01, 0.09]	0.29	6.58	1, 72	.01*	.14
Externalizing[b]	−0.24	0.40	[−1.05, 0.57]	−0.07	0.35	1, 73	.55	.96
Irritability[b]	−0.17	0.65	[−1.46, 1.12]	−0.03	0.07	1, 73	.79	.96
Left lPFC[b]	0.30	0.64	[−0.99, 1.58]	0.06	0.21	1, 70	.65	1.07
Right lPFC[b]	0.03	0.57	[−1.11, 1.16]	0.01	0.002	1, 70	.97	.97
GSR reactivity[b]	0.01	0.002	[0.002, 0.01]	0.36	9.61	1, 66	.003**	.08
GSR recovery[b]	−0.01	0.002	[−0.01, < .001]	−0.24	3.92	1, 66	.05*	.20

Note. CI = confidence interval; *B* = unstandardized coefficient; β = standardized coefficient; p_{Adjusted} = corrected *p* values; lPFC = lateral prefrontal cortex; GSR = galvanic skin response. Outcome variables were regressed on each predictor variable separately, totaling 28 linear regression models. Results exclude three univariate and multivariate outliers.
[a] Denotes predictor variables. [b] Denotes outcome variables.
* $p < .05$. ** $p < .01$.

Neutral Expressions

Although neutral expressions were included as a comparison group, we found robust associations with ER that advance our understanding of early emotional expressions. The present study operationalized neutral expressions as the absence of AUs during frustration onset, which is similar to suppression: the overt inhibition of internal emotional experiences (Gross, 2002; Gross & Thompson, 2007; Rogers et al., 2016). However, the current findings contradict the suppression literature, which has contended that suppression is maladaptive (Braet et al., 2014; Samson et al., 2015), as it has been linked to poor emotional and interpersonal functioning (Gross et al., 2006), and low ER skills (Rogers et al., 2016). In the present study, however, neutral expressions predicted good effortful control skills and modulated physiological reactivity followed by a robust recovery. In other words, children who displayed neutral expressions had feedback-related physiological stress responses (*reactivity*) followed by a strong return to baseline (*recovery*) after frustration onset. This pattern more closely resembles an adaptive and active regulatory process such as *masking*, as children exhibited neutral expressions despite experiencing physiological stress responses, which they down-regulated appropriately. Differences in research methodologies may better explain contradictory findings, as past research on suppression often instructed participants to suppress their emotional reactions or complete questionnaires about their ER strategies (e.g., emotional suppression). In contrast, the present study measured participants' unprompted, naturalistic emotional suppression. Thus, the field should perhaps be more conservative when interpreting neutral expressions, as its regulatory mechanisms seem to be more complex than previously thought and may vary across various factors (e.g., context, severity, etc.).

In addition to predicting a physiological response to frustration onset indicative of adaptive ER, neutral expressions predicted better temperamental effortful control. Effortful control captures children's differing abilities to voluntarily regulate their emotions and reactions (Rueda, 2012). In addition, effortful control has been found to predict regulation of positive and negative feelings (Kochanska et al., 2000) and it is considered a critical component of self-regulation (Cipriano & Stifter, 2010). Therefore, the present findings suggest that naturally occurring neutral expressions during frustration onset may capture children with strong self-regulation skills. These questionnaire-based results are further supported by our findings that children in the neutral expression group could effectively down-regulate their stress response, as measured by GSR, to the frustration-inducing stimuli. The present study also highlights the need for future work on emotion suppression to implement a multimodel design to assess in-the-moment, naturally occurring suppression and its active regulatory mechanisms, as these may be different than when participants are instructed to suppress.

Strengths, Limitations, and Future Directions

This study is, to our knowledge, the first to examine incongruent affect in early childhood using a multimodel design that included neural and physiological changes in addition to parent-reported questionnaires. Other strengths of the study include a robust sample for a pediatric neuroimaging study and the use of a rigorous anatomically based facial coding system. The present study also highlights important considerations and next steps for future work to examine the neural and physiological correlates of incongruent expressions in young children across different paradigms and social contexts. Mixed results between the current findings and past work on incongruent expressions suggest that social context (e.g., mildly interpersonal vs. highly interpersonal) might moderate incongruent affect. However, the current study did not have an explicit social context manipulation as part of the protocol. Future studies employing a similar multimodal approach within varying interpersonal scenarios will further elucidate how social context relates to incongruent affect and its underlying mechanisms.

Similarly, neutral expressions, operationalized as emotional suppression, predicted good self-regulation skills. However, children were not prompted to hide emotions and we cannot differentiate whether neutral expressions reflected suppressed affect versus an absence of strong affect. Although neutral expressions were associated with greater GSR reactivity, strongly implying that children were experiencing frustration-related stress. Nonetheless, the present study sets the stage for future researchers to empirically examine instructed versus naturalistic neutral expressions to understand whether differing regulatory mechanisms drive them during emotional challenges.

Despite the strengths of the present study, it is important to note that it may have been underpowered to detect more subtle effects. Thus, replicating results with an independent and larger sample is an important next step. However, it is also worth noting that recruiting a large sample size of severely irritable preschoolers to participate in a neuroimaging study is extremely difficult, with most published studies having a sample size of under 100 preschool-aged children (Camacho et al., 2021; Deveney et al., 2019; Grabell et al., 2019; Li et al., 2017). By providing the corrected and uncorrected findings, the present study sets a knowledge base for future researchers to perform a similar design with more statistical power.

Differences in findings across measures is another limitation that calls for the replication of the present findings. For instance, complete incongruent smiling predicted poor self-regulation, but this was only true for parental reports of effortful control. Other metrics of ER (e.g., changes in physiology and neural activation) did not significantly predict the same pattern. The discrepancy in results across these three indexes of ER is possibly due to underpower, as the neural and GSR variables had marginal results in the same direction as Effortful Control with medium effect sizes, except for activation on the Left lPFC. It is also worth noting that Effortful Control may have been capturing longstanding patterns across contexts, whereas neural and physiological metrics captured a short, one-time reaction to an emotional challenge and associations between different facial expressions and regulation may be more robust at different levels of analysis.

On average, children's frequency and pattern of negative facial expressions during the ICK task was consistent with the goal of the task to induce mild to moderate frustration. Nonetheless, it is worth noting that, as with all emotion-inducing experiments, there is no ground truth to unequivocally know the internal emotional states of human research participants (Barrett, 2015). Thus, children likely varied in the valence and intensity of their emotional experiences playing the game. It is also likely that there was a wide range of individual differences in the types of emotions children experienced while playing the game.

Although the ICK task was designed to elicit mild to moderate frustration, receiving negative feedback in front of a stranger (e.g., the experimenter) may have induced embarrassment in some children. Embarrassment is often evoked by the publicity of one's behavioral shortcomings (e.g., failing at a task while a stranger watches; Keltner, 1996; Miller, 1996; Müller-Pinzler et al., 2015), and is typically displayed by smiling and averting the head and gaze (Keltner, 1995; Keltner & Buswell, 1997; Nikolić et al., 2016). However, studies on embarrassment typically use more highly social paradigms, such as competing against other humans or performing in front of a crowd (Müller-Pinzler et al., 2015; Nikolić et al., 2016). In the ICK task, children were looking at a monitor away from the experimenter, who was sitting next to and behind them. Thus, the task was not designed to capture children shifting their heads and gaze away from the person evaluating them. Furthermore, studies have shown that embarrassment-related smiles tend to predict lower levels of psychopathology (Nikolić et al., 2016), whereas incongruent smiles in the present study predicted the contrary (e.g., poor effortful control), suggesting the smiling captured in this study was unrelated to embarrassment. Subsequent studies that use different emotion-eliciting stimuli are crucial to building a more robust empirical literature on the mechanisms underlying early affective expressions.

References

Achenbach, T. M., & Rescorla, L. A. (2000). *Manual for the ASEBA preschool forms and profiles* (Vol. 30). University of Vermont, Research Center for Children, Youth, & Families.

Barker, J. W., Aarabi, A., & Huppert, T. J. (2013). Autoregressive model based algorithm for correcting motion and serially correlated errors in fNIRS. *Biomedical Optics Express*, *4*(8), 1366–1379. https://doi.org/10.1364/BOE.4.001366

Barrett, L. F. (2015). Construction as an integrative framework for the science of emotion. In L. F. Barrett & J. A. Russell (Eds.), *The psychological construction of emotion* (pp. 448–458). The Guilford Press.

Barrett, L. F., Adolphs, R., Marsella, S., Martinez, A. M., & Pollak, S. D. (2019). Emotional expressions reconsidered: Challenges to inferring emotion from human facial movements. *Psychological Science in the Public Interest*, *20*(1), 1–68. https://doi.org/10.1177/1529100619832930

Beauchaine, T. P., Gatzke-Kopp, L., & Mead, H. K. (2007). Polyvagal Theory and developmental psychopathology: Emotion dysregulation and conduct problems from preschool to adolescence. *Biological*

Psychology, *74*(2), 174–184. https://doi.org/10.1016/j.biopsycho.2005.08.008

Bongers, I. L., Koot, H. M., van der Ende, J., & Verhulst, F. C. (2003). The normative development of child and adolescent problem behavior. *Journal of Abnormal Psychology*, *112*(2), 179–192. https://doi.org/10.1037/0021-843X.112.2.179

Boucsein, W. (2012). *Electrodermal activity*. Springer Science & Business Media. https://doi.org/10.1007/978-1-4614-1126-0

Boyce, W. T., Quas, J., Alkon, A., Smider, N. A., Essex, M. J., Kupfer, D. J., & The MacArthur Assessment Battery Working Group of the MacArthur Foundation Research Network on Psychopathology and Development. (2001). Autonomic reactivity and psychopathology in middle childhood. *The British Journal of Psychiatry*, *179*(2), 144–150. https://doi.org/10.1192/bjp.179.2.144

Braet, C., Theuwis, L., Van Durme, K., Vandewalle, J., Vandevivere, E., Wante, L., Moens, E., Verbeken, S., & Goossens, L. (2014). Emotion regulation in children with emotional problems. *Cognitive Therapy and Research*, *38*(5), 493–504. https://doi.org/10.1007/s10608-014-9616-x

Cacioppo, J. T., & Sandman, C. A. (1978). Physiological differentiation of sensory and cognitive tasks as a function of warning, processing demands, and reported unpleasantness. *Biological Psychology*, *6*(3), 181–192. https://doi.org/10.1016/0301-0511(78)90020-0

Calkins, S. D., & Dedmon, S. E. (2000). Physiological and behavioral regulation in two-year-old children with aggressive/destructive behavior problems. *Journal of Abnormal Child Psychology*, *28*(2), 103–118. https://doi.org/10.1023/A:1005112912906

Camacho, M. C., Williams, E. M., Ding, K., & Perlman, S. B. (2021). Multimodal examination of emotion processing systems associated with negative affectivity across early childhood. *Developmental Cognitive Neuroscience*, *48*, 100917. https://doi.org/10.1016/j.dcn.2021.100917

Cipriano, E. A., & Stifter, C. A. (2010). Predicting preschool effortful control from toddler temperament and parenting behavior. *Journal of Applied Developmental Psychology*, *31*(3), 221–230. https://doi.org/10.1016/j.appdev.2010.02.004

Cole, P. M. (1986). Children's spontaneous control of facial expression. *Child Development*, *57*(6), 1309–1321. https://doi.org/10.2307/1130411

Cole, P. M., Michel, M. K., & Teti, L. O. D. (1994). The development of emotion regulation and dysregulation: A clinical perspective. *Monographs of the Society for Research in Child Development*, *59*(2–3), 73–100. https://doi.org/10.1111/j.1540-5834.1994.tb01278.x

Cole, P. M., Zahn-Waxler, C., Fox, N. A., Usher, B. A., & Welsh, J. D. (1996). Individual differences in emotion regulation and behavior problems in preschool children. *Journal of Abnormal Psychology*, *105*(4), 518–529. https://doi.org/10.1037/0021-843X.105.4.518

Davis, T. L. (1995). Gender differences in masking negative emotions: Ability of motivation? *Developmental Psychology*, *31*(4), 660–667. https://doi.org/10.1037/0012-1649.31.4.660

DePaulo, B. M., Jordan, A., Irvine, A., & Laser, P. S. (1982). Age changes in the detection of deception. *Child Development*, *53*(3), 701–709. https://doi.org/10.2307/1129383

Deveney, C. M., Briggs-Gowan, M. J., Pagliaccio, D., Estabrook, C. R., Zobel, E., Burns, J. L., Norton, E. S., Pine, D. S., Brotman, M. A., Leibenluft, E., & Wakschlag, L. S. (2019). Temporally sensitive neural measures of inhibition in preschool children across a spectrum of irritability. *Developmental Psychobiology*, *61*(2), 216–227. https://doi.org/10.1002/dev.21792

Eisenberg, N., Fabes, R. A., Guthrie, I. K., Murphy, B. C., Maszk, P., Holmgren, R., & Suh, K. (1996). The relations of regulation and emotionality to problem behavior in elementary school children. *Development and Psychopathology*, *8*(1), 141–162. https://doi.org/10.1017/S095457940000701X

Ekman, P., & Friesen, W. V. (1978). *Facial action coding system (FACS)* [Database record]. APA PsycTests.

Ekman, P., & Friesen, W. V. (1982). Felt, false, and miserable smiles. *Journal of Nonverbal Behavior*, *6*(4), 238–252. https://doi.org/10.1007/BF00987191

Ekman, P., Friesen, W. V., & O'Sullivan, M. (1988). Smiles when lying. *Journal of Personality and Social Psychology*, *54*(3), 414–420. https://doi.org/10.1037/0022-3514.54.3.414

Ekman, P., Roper, G., & Hager, J. C. (1980). Deliberate facial movement. *Child Development*, *51*(3), 886–891. https://doi.org/10.2307/1129478

ELAN. (2020). ELAN (Version 6.0) [Computer software]. Max Planck Institute for Psycholinguistics, The Language Archive. https://archive.mpi.nl/tla/elan

Feldman, R. S., Jenkins, L., & Popoola, O. (1979). Detection of deception in adults and children via facial expressions. *Child Development*, *50*(2), 350–355. https://doi.org/10.2307/1129409

Fowles, D. C. (1987). Application of a behavioral theory of motivation to the concepts of anxiety and impulsivity. *Journal of Research in Personality*, *21*(4), 417–435. https://doi.org/10.1016/0092-6566(87)90030-4

Frick, P. J., Barry, C. T., & Kamphaus, R. W. (2010). *Clinical assessment of child and adolescent personality and behavior*. Springer International Publishing. https://doi.org/10.1007/978-1-4419-0641-0

Goldin, P. R., McRae, K., Ramel, W., & Gross, J. J. (2008). The neural bases of emotion regulation: Reappraisal and suppression of negative emotion. *Biological Psychiatry*, *63*(6), 577–586. https://doi.org/10.1016/j.biopsych.2007.05.031

Grabell, A. S., Huppert, T. J., Fishburn, F. A., Li, Y., Hlutkowsky, C. O., Jones, H. M., Wakschlag, L. S., & Perlman, S. B. (2019). Neural correlates of early deliberate emotion regulation: Young children's responses to interpersonal scaffolding. *Developmental Cognitive Neuroscience*, *40*, 100708. https://doi.org/10.1016/j.dcn.2019.100708

Grabell, A. S., Huppert, T. J., Fishburn, F. A., Li, Y., Jones, H. M., Wilett, A. E., Bemis, L. M., & Perlman, S. B. (2018). Using facial muscular movements to understand young children's emotion regulation and concurrent neural activation. *Developmental Science*, *21*(5), e12628. https://doi.org/10.1111/desc.12628

Grabell, A. S., Jones, H. M., Wilett, A. E., Bemis, L. M., Wakschlag, L. S., & Perlman, S. B. (2020). Children's facial muscular movements and risk for early psychopathology: Assessing clinical utility. *Behavior Therapy*, *51*(2), 253–267. https://doi.org/10.1016/j.beth.2019.08.004

Grabell, A. S., Olson, S. L., Tardif, T., Thompson, M. C., & Gehring, W. J. (2017). Comparing self-regulation-associated event related potentials in preschool children with and without high levels of disruptive behavior. *Journal of Abnormal Child Psychology*, *45*(6), 1119–1132. https://doi.org/10.1007/s10802-016-0228-7

Gross, J. J. (2002). Emotion regulation: Affective, cognitive, and social consequences. *Psychophysiology*, *39*(3), 281–291. https://doi.org/10.1017/S0048577201393198

Gross, J. J., Richards, J. M., & John, O. P. (2006). Emotion regulation in everyday life. In D. K. Snyder, J. Simpson, & J. N. Hughes (Eds.), *Emotion regulation in couples and families: Pathways to dysfunction and health* (pp. 13–35). American Psychological Association. https://doi.org/10.1037/11468-001

Gross, J. J., & Thompson, R. A. (2007). Emotion regulation: Conceptual foundations. In J. J. Gross (Ed.), *Handbook of emotion regulation* (pp. 3–24). Guilford Press.

IBM Corp. (2016). IBM SPSS Statistics for Windows (Version 24.0).

Kadziolka, M. J., Di Pierdomenico, E. A., & Miller, C. J. (2016). Trait-like mindfulness promotes healthy self-regulation of stress. *Mindfulness*, *7*(1), 236–245. https://doi.org/10.1007/s12671-015-0437-0

Keltner, D. (1995). Signs of appeasement: Evidence for the distinct displays of embarrassment, amusement, and shame. *Journal of Personality and Social Psychology*, *68*(3), 441–454. https://doi.org/10.1037/0022-3514.68.3.441

Keltner, D. (1996). Evidence for the distinctness of embarrassment, shame, and guilt: A study of recalled antecedents and facial expressions of emotion. *Cognition and Emotion*, *10*(2), 155–172. https://doi.org/10.1080/026999396380312

Keltner, D., & Buswell, B. N. (1997). Embarrassment: Its distinct form and appeasement functions. *Psychological Bulletin*, *122*(3), 250–270. https://doi.org/10.1037/0033-2909.122.3.250

Kim, S. H., & Hamann, S. (2007). Neural correlates of positive and negative emotion regulation. *Journal of Cognitive Neuroscience*, *19*(5), 776–798. https://doi.org/10.1162/jocn.2007.19.5.776

Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology*, *36*(2), 220–232. https://doi.org/10.1037/0012-1649.36.2.220

Li, Y., Grabell, A. S., Wakschlag, L. S., Huppert, T. J., & Perlman, S. B. (2017). The neural substrates of cognitive flexibility are related to individual differences in preschool irritability: A fNIRS investigation. *Developmental Cognitive Neuroscience*, *25*, 138–144. https://doi.org/10.1016/j.dcn.2016.07.002

Liew, J., Eisenberg, N., & Reiser, M. (2004). Preschoolers' effortful control and negative emotionality, immediate reactions to disappointment, and quality of social functioning. *Journal of Experimental Child Psychology*, *89*(4), 298–319. https://doi.org/10.1016/j.jecp.2004.06.004

McDowell, D. J., O'Neill, R., & Parke, R. D. (2000). Display rule application in a disappointing situation and children's emotional reactivity: Relations with social competence. *Merrill-Palmer Quarterly*, *46*(2), 306–324. https://www.jstor.org/stable/23093718

Miller, R. S. (1996). *Embarrassment: Poise and peril in everyday life*. Guilford Press.

Morgan, E. (2017). *All about EDA Part 1: Introduction to electrodermal activity*. MindWare Technologies LTD. https://support.mindwaretech.com

Müller-Pinzler, L., Gazzola, V., Keysers, C., Sommer, J., Jansen, A., Frässle, S., Einhäuser, W., Paulus, F. M., & Krach, S. (2015). Neural pathways of embarrassment and their modulation by social anxiety. *NeuroImage*, *119*, 252–261. https://doi.org/10.1016/j.neuroimage.2015.06.036

Nikolić, M., Colonnesi, C., de Vente, W., & Bögels, S. M. (2016). Blushing in early childhood: Feeling coy or socially anxious? *Emotion*, *16*(4), 475–487. https://doi.org/10.1037/emo0000131

Perlman, S. B., Jones, B. M., Wakschlag, L. S., Axelson, D., Birmaher, B., & Phillips, M. L. (2015). Neural substrates of child irritability in typically developing and psychiatric populations. *Developmental Cognitive Neuroscience*, *14*, 71–80. https://doi.org/10.1016/j.dcn.2015.07.003

Perlman, S. B., Luna, B., Hein, T. C., & Huppert, T. J. (2014). fNIRS evidence of prefrontal regulation of frustration in early childhood. *NeuroImage*, *85*(1), 326–334. https://doi.org/10.1016/j.neuroimage.2013.04.057

Putnam, S. P., & Rothbart, M. K. (2006). Development of short and very short forms of the Children's Behavior Questionnaire. *Journal of Personality Assessment*, *87*(1), 102–112. https://doi.org/10.1207/s15327752jpa8701_09

Rogers, M. L., Halberstadt, A. G., Castro, V. L., MacCormack, J. K., & Garrett-Peters, P. (2016). Maternal emotion socialization differentially predicts third-grade children's emotion regulation and lability. *Emotion*, *16*(2), 280–291. https://doi.org/10.1037/emo0000142

Rothbart, M. K., Ahadi, S. A., Hershey, K. L., & Fisher, P. (2001). Investigations of temperament at three to seven years: The Children's Behavior Questionnaire. *Child Development*, *72*(5), 1394–1408. https://doi.org/10.1111/1467-8624.00355

Rothbaum, F., & Weisz, J. R. (1994). Parental caregiving and child externalizing behavior in nonclinical samples: A meta-analysis. *Psychological Bulletin*, *116*(1), 55–74. https://doi.org/10.1037/0033-2909.116.1.55

Rueda, M. R. (2012). Effortful control. In M. Zentner & R. L. Shiner (Eds.), *Handbook of temperament* (pp. 145–167). Guilford Press.

Rydell, A. M., Berlin, L., & Bohlin, G. (2003). Emotionality, emotion regulation, and adaptation among 5- to 8-year-old children. *Emotion*, *3*(1), 30–47. https://doi.org/10.1037/1528-3542.3.1.30

Saarni, C. (1979). Children's understanding of display rules for expressive behavior. *Developmental Psychology*, *15*(4), 424–429. https://doi.org/10.1037/0012-1649.15.4.424

Saarni, C. (1984). An observational study of children's attempts to monitor their expressive behavior. *Child Development*, *55*(4), 1504–1513. https://doi.org/10.2307/1130020

Samson, A. C., Hardan, A. Y., Podell, R. W., Phillips, J. M., & Gross, J. J. (2015). Emotion regulation in children and adolescents with autism spectrum disorder. *Autism Research*, *8*(1), 9–18. https://doi.org/10.1002/aur.1387

Santosa, H., Zhai, X., Fishburn, F., & Huppert, T. (2018). The NIRS brain AnalyzIR toolbox. *Algorithms*, *11*(5), 73. https://doi.org/10.3390/a11050073

Silvers, J. A., Shu, J., Hubbard, A. D., Weber, J., & Ochsner, K. N. (2015). Concurrent and lasting effects of emotion regulation on amygdala response in adolescence and young adulthood. *Developmental Science*, *18*(5), 771–784. https://doi.org/10.1111/desc.12260

Stringaris, A., Vidal-Ribas, P., Brotman, M. A., & Leibenluft, E. (2018). Practitioner review: Definition, recognition, and treatment challenges of irritability in young people. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *59*(7), 721–739. https://doi.org/10.1111/jcpp.12823

Swinehart, D. F. (1962). The beer-lambert law. *Journal of Chemical Education*, *39*(7), 333. https://doi.org/10.1021/ed039p333

Tsujii, T., Okada, M., & Watanabe, S. (2010). Effects of aging on hemispheric asymmetry in inferior frontal cortex activity during belief-bias syllogistic reasoning: A near-infrared spectroscopy study. *Behavioural Brain Research*, *210*(2), 178–183. https://doi.org/10.1016/j.bbr.2010.02.027

Wakschlag, L. S., Choi, S. W., Carter, A. S., Hullsiek, H., Burns, J., McCarthy, K., Leibenluft, E., & Briggs-Gowan, M. J. (2012). Defining the developmental parameters of temper loss in early childhood: Implications for developmental psychopathology. *Journal of Child Psychology and Psychiatry, and Allied Disciplines*, *53*(11), 1099–1108. https://doi.org/10.1111/j.1469-7610.2012.02595.x

Wakschlag, L. S., Perlman, S. B., Blair, R. J., Leibenluft, E., Briggs-Gowan, M. J., & Pine, D. S. (2018). The neurodevelopmental basis of early childhood disruptive behavior: Irritable and callous phenotypes as exemplars. *The American Journal of Psychiatry*, *175*(2), 114–130. https://doi.org/10.1176/appi.ajp.2017.17010045

Wasserstein, R. L., & Lazar, N. A. (2016). The ASA's statement on *p*-values: Context, process, and purpose. *The American Statistician*, *70*(2), 129–133. https://doi.org/10.1080/00031305.2016.1154108

Wilcox, T., & Biondi, M. (2015). fNIRS in the developmental sciences. *WIREs Cognitive Science*, *6*(3), 263–283. https://doi.org/10.1002/wcs.1343

Zeman, J., Klimes-Dougan, B., Cassano, M., & Adrian, M. (2007). Measurement issues in emotion research with children and adolescents. *Clinical Psychology: Science and Practice*, *14*(4), 377–401. https://doi.org/10.1111/j.1468-2850.2007.00098.x

(*Appendix follows*)

Appendix

Exploring Whether Predictor Variables Uniquely Predict Outcome Variables

Table A1
Results of Simultaneous Linear Regression Models

Model	*B*	*SE*	95% CI [LL, UL]	β	*F*	*df*	*p*
Effortful control[a]							
Complete incongruent smiling	−0.02	0.03	[−0.07, 0.03]	−0.12	1.60	4, 68	.44
Partial incongruent smiling	0.003	0.04	[−0.08, 0.08]	0.01	1.60	4, 68	.94
Negative expressions	−0.06	0.13	[−0.32, 0.20]	−0.06	1.60	4, 68	.64
Neutral expressions	0.04	0.03	[−0.02, 0.09]	0.20	1.60	4, 68	.19
Externalizing[a]							
Complete incongruent smiling	0.98	0.50	[−0.02, 1.98]	0.06	1.10	4, 69	.06
Partial incongruent smiling	−0.78	0.80	[−2.35, 0.83]	0.35	1.10	4, 69	.35
Negative expressions	2.36	2.57	[−2.76, 7.48]	0.36	1.10	4, 69	.36
Neutral expressions	0.32	0.53	[−0.75, 1.38]	0.56	1.10	4, 69	.56
Irritability[a]							
Complete incongruent smiling	1.30	0.81	[−0.31, 2.92]	0.26	0.70	4, 69	.11
Partial incongruent smiling	−1.00	1.28	[−3.56, 1.56]	−0.11	0.70	4, 69	.44
Negative expressions	1.47	4.14	[−6.79, 9.73]	0.05	0.70	4, 69	.72
Neutral expressions	0.52	0.86	[−1.20, 2.23]	0.09	0.70	4, 69	.55
Left lPFC[a]							
Complete incongruent smiling	−0.44	0.81	[−2.05, 1.17]	−0.09	1.20	4, 66	.59
Partial incongruent smiling	2.24	1.26	[−0.28, 4.75]	0.25	1.20	4, 66	.08
Negative expressions	1.26	4.05	[−6.82, 9.34]	0.04	1.20	4, 66	.76
Neutral expressions	0.39	0.84	[−1.28, 2.06]	0.07	1.20	4, 66	.64
Right lPFC[a]							
Complete incongruent smiling	−1.31	0.70	[−2.72, 0.09]	−0.30	1.46	4, 66	.07
Partial incongruent smiling	1.01	1.10	[−1.19, 3.21]	0.13	1.46	4, 66	.36
Negative expressions	2.88	3.54	[−4.19, 9.95]	0.11	1.46	4, 66	.42
Neutral expressions	−0.65	0.73	[−2.12, 0.81]	−0.14	1.46	4, 66	.38
GSR reactivity[a]							
Complete incongruent smiling	<0.001	0.002	[−0.01, 0.01]	0.02	2.24	4, 62	.90
Partial incongruent smiling	−0.002	0.004	[−0.01, 0.01]	−0.07	2.24	4, 62	.63
Negative expressions	−0.002	0.01	[−0.03, 0.02]	−0.02	2.24	4, 62	.89
Neutral expressions	0.01	0.003	[< 0.001, .01]	0.34	2.24	4, 62	.03**
GSR recovery[a]							
Complete incongruent smiling	0.002	0.003	[−0.004, 0.01]	0.13	1.51	4, 62	.44
Partial incongruent smiling	−0.01	0.01	[−0.02, 0.004]	−0.19	1.51	4, 62	.21
Negative expressions	0.01	0.02	[−0.03, 0.04]	0.05	1.51	4, 62	.74
Neutral expressions	−0.01	0.003	[−0.01, 0.002]	−0.22	1.51	4, 62	.17

Note. CI = confidence interval; *B* = unstandardized coefficient; β = standardized coefficient; lPFC = lateral prefrontal cortex; GSR = galvanic skin response. Results exclude three univariate and multivariate outliers.

[a] Denotes outcome variables

** $p < .01$.

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