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RESEARCH ARTICLE

Autonomic nervous system reactivity and preschoolers' social dominance

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Abstract

The purpose of this study was to investigate the role of skin conductance level reactivity (SCLR) and respiratory sinus arrhythmia reactivity (RSAR) in preschoolers' social dominance, as well as potential gender differences in these associations. Reactivity was assessed in response to viewing videos of social exclusion and a post-aggression discussion. In a community sample of 94 preschool children followed over one calendar year, reactivity to the post-aggression discussion, but not exclusion, video was related to social dominance. Specifically, increased RSAR to the post-aggression discussion video was positively associated with concurrent social dominance for both boys and girls. Longitudinally, for boys only, coactivation (i.e., increases in SCLR accompanied by increases in RSAR) to the post-aggression discussion video, which may reflect dysregulated, emotionally labile reactions to stress, was associated with relatively low levels of social dominance across the course of the year. Overall, findings contribute to a growing literature documenting the role of autonomic reactivity in preschoolers' social adjustment and extend this work to their capacity to achieve and maintain socially dominant positions with peers.

KEYWORDS
autonomic nervous system, gender, preschool, respiratory sinus arrhythmia, skin conductance, social dominance

1 | INTRODUCTION

Social dominance is an evolutionarily adaptive trait that helps to ensure survival, growth, and development via resource acquisition (Charlesworth, 1996; Hawley, 1999). Socially dominant individuals are those who successfully control material and social resources through the use of coercive, assertive, and prosocial control strategies (Hawley, 2002). This flexible repertoire of resource control strategies to gain and maintain dominance may be seen as early as the preschool period (Hawley, 1999, 2003; Ostrov & Guzzo, 2015; Pellegrini et al., 2011; Roseth et al., 2007; Sluckin & Smith, 1977). Although a variety of strategies may be used to achieve social dominance, and these strategies are related to their own adjustment outcomes (e.g., Roseth et al., 2007), the achievement of social dominance may be an indicator of social competence (Vaughn et al., 2009). Therefore, it is important to understand what may influence the development of social dominance.

One potentially important predictor of social dominance is one's ability to regulate physiological arousal, including functioning of the autonomic nervous system (ANS). In fact, autonomic reactivity and regulation have been linked to social engagement and social behavior (Porges, 2007). Furthermore, emerging research suggests that the sympathetic and parasympathetic branches of the ANS interact to predict children's social behavior and adjustment (El-Sheikh et al., 2009). The present study investigated the joint role of respiratory sinus arrhythmia (an index of parasympathetic nervous system [PNS] influence on the heart; El-Sheikh & Erath, 2011) and skin conductance level (an index of sympathetic nervous system [SNS] activity reflecting sweating influenced by the eccrine sweat glands; Dawson et al., 2017) reactivity in concurrent and future levels of social dominance in preschool-aged children. As dominance strategies may look different and have differential outcomes across genders (Charlesworth & Dzur, 1987; Hawley, 1999; Sebanc et al., 2003), we also investigated whether the physiological correlates of social dominance differed for boys versus girls. Finally, given evidence of the importance of matching stressor stimuli with developmental outcomes of interest (Obradović et al., 2011), we tested physiological reactivity to viewing videos depicting behaviors relevant to social dominance: (1) social exclusion, a type of relational aggression (i.e., using the relationship or the threat of the removal of the relationship as a means of harm; Crick & Grotpeter, 1995) and (2) a post-aggression discussion which resolved the social exclusion showed in the previous clip.

1.1 | Social dominance

Social dominance is a fundamental component of human societies (Hawley, 1999) and is defined as control of resources based on interactions with others (Bjorklund & Pellegrini, 2000; Ostrov & Guzzo, 2015). Thus, operationalizations of social dominance focus on control of and access to resources such as preferred toys, attractive activities, or attention from peers (see Vaughn et al., 2009). For instance, social dominance in preschoolers may be measured by assessing which children get access to what they want in the classroom at the expense of others (Hawley, 2002, 2003), children's ability to be the first to gain access to resources (e.g., first to be able to join a party; Pellegrini et al., 2007), or children's tendency to control the behavior of others (e.g., telling others what to do; Pellegrini et al., 2007). In addition to material gains, socially dominant children appear to benefit from a variety of social advantages. For instance, social dominance is positively related to attention, likability, and positive teacher and peer perception (Pellegrini et al., 2007; see Hawley, 1999, 2007 for review).

Research indicates that children in early childhood, including the preschool period (e.g., Ostrov & Guzzo, 2015), engage in a variety of behaviors to achieve socially dominant positions, including assertive, coercive, manipulative, and prosocial strategies (Charlesworth & Dzur, 1987; Keating & Heltman, 1994; Ostrov & Guzzo, 2015; Pellegrini et al., 2007, 2011). Preschoolers use reconciliation and affiliation (Pellegrini et al., 2007), prosocial behaviors (e.g., Ostrov & Guzzo, 2015), and cooperation (Charlesworth & Dzur, 1987; Pellegrini et al., 2007) to obtain control of resources such as toys, attention, and activities. An example of a prosocial strategy is a child working collaboratively with another child to gain access to a preferred activity (e.g., sharing crayons so both children may draw). However, coercive strategies, including aggressive behavior, have also been found to be an effective tool to gain social dominance in the preschool period (Hawley, 1999; Pettit et al., 1990). An example of a coercive strategy is a child snatching a desired toy out of another child's hand. Interestingly, whereas some youth rely on either a prosocial or coercive behavioral approach, others strategically employ both strategies in their efforts to achieve social dominance (Hawley, 1999, 2015). For example, after snatching a toy from another child, the dominant child may attempt reconciliation by offering to share the toy. Moreover, the ability to flexibly use multiple behavior strategies appears to be associated with the highest levels of social dominance (Hawley, 2014).

Although a variety of behaviors may be used to achieve social dominance, a critical contribution of Hawley's (2002) theoretical approach is its focus on the function (i.e., achievement of resources) rather than form (i.e., prosocial or coercive) of socially dominant behaviors. In fact, theorists argue that social dominance is a meaningful developmental outcome in and of itself with important implications for adjustment (Hawley, 2002). Indeed, once social dominance relationships are in place, specific strategies are often used with less frequency (Pellegrini, 2003), implying that dominance is unique from the behaviors used to facilitate it. Further, specific behaviors, such as aggression, are not uniformly associated with social dominance. For instance, some aggressors may be dysregulated and rejected by peers, whereas others may effectively use aggression to gain dominance and power (Hawley, 2015). In fact, aggression and social dominance (as well as prosocial behavior and social dominance) are often only moderately correlated (e.g., *r*s of 0.23–0.41 between prosocial behavior and social dominance in early childhood concurrently and longitudinally, Ostrov & Guzzo, 2015; *r*s of 0.25 and 0.33 between indices of aggression and social dominance Pellegrini et al., 2011).

Moreover, the outcomes associated with social dominance often differ from those associated with aggressive or prosocial behavior. For example, Ostrov et al. (2006) found that social dominance achieved through non-aggressive means predicted peer acceptance, whereas aggressive behavior predicted peer rejection in a sample of preschoolers. Given the differing outcomes for social dominance compared to other social behaviors, it is important to understand the specific factors that underlie children's achievement of social dominance. It is possible, for instance, that regardless of the specific behaviors used, well-regulated responses to social interchanges may underlie functional competitiveness and in turn social dominance. In fact, Hawley (1999) posited that children's impulse control and emotion regulation contribute to their ability to gain or maintain resources, and previous work suggests that self-regulation may play an important role in young children's ability to choose effective responses when conflicts arise (Fabes et al., 1993).

1.2 | Social dominance and respiratory sinus arrhythmia

Given the hypothesized role of emotional reactivity and regulation in social dominance, physiological systems tied to emotional responses may relate to children's capacity to achieve dominant positions in the peer group. According to polyvagal theory (Porges, 2007), functioning of the ANS plays a critical role in social engagement and social behavior. Porges (2007) argues that flexible increases and decreases of the

PNS, also known as the “rest and digest” system, are vital to adaptation to challenges. The PNS is a fast-acting system that has a dampening effect on stress response systems such as the SNS and hypothalamic-pituitary-adrenal axis. Whereas increased PNS activity (also called augmentation) facilitates calm states and supports social engagement with others in relatively safe contexts, decreased PNS activity (also called withdrawal) facilitates the mobilization of metabolic resources for coping with stressors or threat (Porges, 2007). One common method for measuring PNS influences on the heart is through respiratory sinus arrhythmia (RSA), which is the rhythmic fluctuation of heart rate during spontaneous breathing (Porges, 1995).

When facing an environmental challenge, some researchers have argued that decreased RSA activity reflects an adaptive mobilization of metabolic resources to engage and cope with the stressor (Keller & El-Sheikh, 2009). Consistent with this perspective, meta-analytic findings from studies with children and adolescents indicate that greater RSA decreases to stress are related to lower externalizing behaviors and, in community samples, higher social skills and status among peers (e.g., Graziano & Derefinko, 2013). However, the implications of decreased RSA activity for adjustment are equivocal. In contrast to findings from Graziano and Derefinko (2013) with children and adolescents, meta-analytic work with adults indicates that greater RSA decreases to negative emotion induction are related to externalizing problems (Beauchaine et al., 2019), and Beauchaine and Thayer (2015) argue that excessive RSA decreases to negative events reflect emotional lability and thus serve as a risk factor for poor adjustment. Hastings and colleagues (2008) suggest that adaptive RSA responses will depend on whether the context requires the mobilization of resources for coping versus calming responses that support social engagement. Therefore, different patterns of RSA reactivity (RSAR) may be associated with social dominance depending on the social context.

1.3 | Interactions between respiratory sinus arrhythmia and skin conductance

The implications of RSAR for adjustment may also depend on activity in the SNS, which coordinates the body’s “fight or flight” response. When measured via indices that innervate the same organ system (e.g., the heart), the PNS and SNS have opposing effects on arousal; thus, they can function in a reciprocal manner such that increased activity of one branch is accompanied by decreased activity of the other, resulting in both branches exerting the same directional effect on arousal (El-Sheikh et al., 2009). For instance, reciprocal SNS activity (i.e., SNS increases, PNS decreases) is associated with increased physiological arousal (e.g., increases in heart rate). Reciprocal SNS activation is thought to promote adaptive functioning, such that children feel aroused in the presence of a stressor and are mobilized to act but likely still behave adaptively (e.g., seeking out supports, reducing exposure to stressors; El-Sheikh et al., 2009). Reciprocal parasympathetic activity (i.e., PNS increases, SNS decreases) is associated with decreased physiological arousal and has been theorized to occur when a child does not interpret an event as particularly dangerous; this pattern may reflect self-soothing (El-Sheikh et al., 2009).

Less is known about the two non-reciprocal profiles, but they may be maladaptive given that the two systems are working in opposition to each other. Coactivation (i.e., increased activity of both the PNS and SNS) has been postulated to reflect physiological overarousal, wherein the SNS overrides the insufficient PNS response to the stressor, causing a dysregulated response (El-Sheikh & Erath, 2011). Similarly, coinhibition (i.e., decreased activity of both the PNS and SNS) has been hypothesized as an ambiguous response to stress (El-Sheikh & Erath, 2011) and in response to laboratory challenges has been associated with externalizing behavior (e.g., Beauchaine et al., 2007; Boyce et al., 2001; but see Keller & El-Sheikh, 2009).

Given ties between social dominance and emotion reactivity and regulation, we hypothesized that reciprocal patterns of ANS reactivity would support the achievement and maintenance of social dominance, whereas non-reciprocal patterns of ANS reactivity would be related to low social dominance. In the present study, SNS reactivity was measured via skin conductance level reactivity (SCLR), with greater SCLR reflecting heightened sweat gland activity and increased SNS activity to task relative to baseline (Dawson et al., 2017).

1.4 | Present study

In the present study, we investigated associations between RSAR and SCLR, as well as their interactions, and social dominance both concurrently in the spring of the preschool year as well as longitudinally across the course of one calendar year. Some previous research has documented differences in associations between physiology and outcomes depending on whether they are assessed concurrently or over time (e.g., Obradović et al., 2010). Further, Pellegrini and colleagues (2011) argue that there may be distinct correlates of the *establishment* versus *maintenance* of socially dominant positions in the peer group. These authors also suggest that, because social positions in the peer group are established at the beginning of the school year, correlates of social dominance in the second half of the year often reflect factors associated with the *maintenance* of social dominance (Pellegrini et al., 2011). Thus, in the present study, concurrent associations between RSAR and SCLR and social dominance, which were measured during the spring of preschool, may be most closely tied to the maintenance of social dominance. In contrast, longitudinal associations reflect physiological patterns that predict *changes* in dominance over the calendar year, often across transitions to new classrooms and the formation of new peer groups. Therefore, longitudinal associations likely reflect physiological patterns related to children’s ability to both establish social dominance across these transitions, as well as their ability to maintain their social dominance positions across the academic year. As well-regulated, reciprocal patterns of physiological reactivity are hypothesized to reflect adaptive functioning (El-Sheikh et al., 2009), and thus may support the establishment as well as maintenance of social dominance, we hypothesized that reciprocal patterns of ANS responding (i.e., increased RSAR accompanied by decreased SCLR; decreased RSAR accompanied by increased SCLR) would be related to higher social dominance both concurrently and over the course of the calendar year.

Mounting research also highlights the importance of stimuli used to assess physiological reactivity. In fact, researchers have found distinct associations between autonomic reactivity and social behavior and adjustment based on the stimuli used (Obradović et al., 2011). Following recommendations by Obradović and collagues (2011), we selected video stimuli that matched our outcome of interest: social dominance during the preschool period. Specifically, the first video depicted expressions of dominance (i.e., controlling access to the desired resource of peer acceptance and inclusion), in which a *Sesame Street* character refuses to let Big Bird join a club while using verbal insults as justifications for the social exclusion. The second video depicted Big Bird engaging in a discussion of the exclusion experience with supportive others. This video was selected because affiliation and post-aggression reconciliation, such as efforts to restore a positive relationship with the target of the aggression via friendly overtures including apologizing or sharing access to resources, are common among socially dominant preschoolers (Pellegrini et al., 2007, 2011; Roseth et al., 2007). Thus, physiological regulation to this video may reflect children's regulation to supportive, affiliative interactions as well as managing the fallout of aggressive episodes. Given the hypothesized importance of impulse control and emotion regulation for social dominance (Hawley, 1999), we expected that reciprocal patterns of reactivity to both depictions of exclusion and a post-aggression discussion would be associated with social dominance.

Associations between ANS activity and social dominance may also depend on child gender. Dominance may look different across genders (Charlesworth & Dzur, 1987; Hawley, 1999; Ostrov & Keating, 2004), which raises the question of whether the underlying physiological processes mimic these differences. For example, boys may use more overly coercive strategies than girls, who may assert dominance through more subtle means (Hawley, 1999). Additionally, some researchers have called for the separate consideration of physiological profiles for boys and girls (El-Sheikh et al., 2009), in part because previous research has demonstrated that the physiological profiles associated with risk differ by gender (e.g., Daoust et al., 2018; El-Sheikh et al., 2007). Thus, we conducted exploratory analyses to investigate whether patterns of physiological reactivity were differentially associated with social dominance for boys and girls.

Finally, we included robustness tests examining whether associations between RSAR and SCLR and social dominance remained even when controlling for two behaviors closely tied to social dominance: prosocial and aggressive behavior. Prior research has documented associations between RSAR and/or SCLR and aggression (e.g., Calkins & Dedmon, 2000; Murray-Close et al., 2014) as well as prosocial behavior (e.g., Beauchaine et al., 2013; Erath & Tu, 2014). However, as social dominance can be achieved through a wide range of means including both affiliative and coercive strategies (Hawley, 1999), and social dominance is only moderately correlated with behaviors such as aggression (e.g., Pellegrini et al., 2011) and prosocial behavior (Ostrov & Guzzo, 2015), we expected that associations between RSAR and SCLR and social dominance would remain even when these behaviors were controlled.

In sum, the goal of the present study was to investigate concurrent and longitudinal associations between RSAR, SCLR, and their interaction in the prediction of social dominance in a sample of preschool children. Physiological reactivity was assessed while children watched age-appropriate videos matching the outcome of social dominance (i.e., control of access to peer inclusion via exclusion, a post-aggression discussion with the victim). We hypothesized that reciprocal patterns (i.e., increased RSAR accompanied by decreased SCLR; decreased RSAR accompanied by increased SCLR) to viewing these videos would be associated with social dominance concurrently and over time. In contrast, we expected that non-reciprocal patterns to both videos would be associated with relatively low levels of social dominance. We also investigated gender differences in physiological correlates of social dominance and role of aggression and prosocial behavior as exploratory aims of the study. Finally, we conducted robustness tests to determine whether associations persisted even when aggressive and prosocial behavior were controlled.

2 | MATERIALS AND METHODS

2.1 | Participants

Participants were drawn from a large, multi-cohort, longitudinal study examining temperamental pathways to aggression in a large northeastern city and surrounding suburbs. The cohorts were recruited from 10 National Association for the Education of Young Children accredited or recently accredited early childhood education centers that were chosen to reflect the surrounding community (see Ostrov et al., 2019). All children in participating classrooms were eligible to participate, and children were ages 3–4 years at the first assessment period. Of the 300 participants fully consented to the study, 94 children (43 girls; at study enrollment M_{age} = 45.49 months, SD = 3.79) came into the lab to complete physiological measures. Of these 94 participants, one was dropped due to completing physiology assessments at a different time point than the rest of the group (Time 3 as opposed to the Time 1 summer), and one other participant was dropped from analyses as they had missing data for all the variables of interest. Participants' racial/ethnic composition was 3.2% African American/Black, 9.7% Asian/Pacific Islander, 69.9% White, 1.1% Hispanic/Latinx, and 15.1% multiracial. One participant (1.1%) was missing race/ethnicity. Based on coding from the Hollingshead's (1975) nine-point scoring system (i.e., 9 = executives and professionals, 1 = service workers) of parents' occupation, the sample was, on average, middle class (M = 7.88, SD = 1.33).

2.2 | Procedure

Procedures from the study that the data were drawn from were approved by the local institutional review board. Data were collected over a 4-year period with one cohort newly enrolled each year; each cohort participated in the spring/summer (T1) and was followed over into the following fall, approximately 6 months later (T2), and the following spring, approximately 1 year later (T3). Time points across cohorts were consistent, and data were collected across the same time span each year for each cohort. In the present study, data from T1 (spring/summer, year 1) and T3 (spring, year 2) across the four cohorts were combined to examine study questions. During T1, parental consent forms were distributed to families at their preschools and those who returned the consent forms were included in the study. During T1 and T3, each research assistant spent a substantial amount of time in the participants' classrooms (approximately 2 months at each time point) conducting naturalistic observations of aggression, victimization, and other social behaviors using the Early Childhood Observation System (e.g., Godleski et al., 2015). Observers were rigorously trained in complex observational coding protocols (see Ostrov & Keating, 2004). Of the multiple observers in a room, one research assistant per room who observed a given child was randomly selected to complete the packet of questionnaires on behavior, including social dominance, for that child.

Consented families were also invited via phone and email to come into the lab during the summer following T1 observations to participate in physiological data collection. Following procedures developed by Calkins and Keane (2004) to measure baseline RSA and RSAR in young children, baseline ANS activity (i.e., SCL and RSA) was assessed as participants viewed a neutral video clip. To measure physiological reactivity to social exclusion and the post-aggression discussion, children then watched additional videos: (1) depicting exclusion (video 1) and (2) a discussion of the victimization experience with supportive others (video 2). Children and their parents were compensated with a $30 gift certificate and a small toy for their participation.

2.3 | Measures

2.3.1 | Observer ratings of social dominance, prosocial behavior, and aggression

Research assistant observers completed the Ratings of Resource Control and Influence among Peers-Research Assistant Report to assess social dominance. Data were collected at T1 and T3 of the larger study. This six-item measure has acceptable psychometrics (Hawley, 2003; Ostrov et al., 2006; Ostrov & Guzzo, 2015) and provides an assessment of the observer's perception of each child's tendency to obtain resources and attention in the classroom. Items include assessments of access to preferred activities (e.g., "This child gets the best roles in class activities"), degree of attention received (e.g., "This child usually gets attention from others"), and the degree to which the child gains access to resources at the expense of others (e.g., "This child usually gets what s/he wants, even if others don't"), which are important potential markers of social dominance in early childhood (Vaughn et al., 2009). These items are measured on a five-point scale (1 = *Never or almost never true* to 5 = *Always or almost always true*). After spending several months in the classrooms observing the participating children, research assistants have been found to be valid and reliable informants of these behaviors using similar rating forms in previous studies (e.g., Blakely-McClure & Ostrov, 2018; Perry & Ostrov, 2018). In the present study, observer reports demonstrated good reliability both at T1 (Cronbach's $\alpha = 0.86$) and T3 (Cronbach's $\alpha = 0.88$).

Research assistants also completed the Child Behavior Scale (CBS; Ladd & Profilet, 1996) at T1, which is a measure of young children's behavior toward peers in classroom contexts. Research assistants rated children's aggressive (seven items; e.g., "fights with other children") and prosocial behavior toward peers (seven items; e.g., "helps other children") on a three-point scale (1 = *doesn't apply* to 3 = *certainly applies*). Prior research suggests that the subscale scores are internally consistent, relatively stable, and distinct (Ladd et al., 2009; Ladd & Profilet, 1996). Although originally developed as a teacher-report measure, the CBS has previously been shown to be reliable and associated with teacher reports when completed by research assistants (Perry & Ostrov, 2018). In the present study, observer ratings of the aggression and prosocial behavior subscale demonstrated good internal consistency (Cronbach's $\alpha = 0.87$ and Cronbach's $\alpha = 0.92$, respectively).

2.3.2 | Physiological measures: Skin conductance and respiratory sinus arrhythmia

The physiological equipment was first explained in a developmentally appropriate manner (e.g., children applied sham electrodes onto a stuffed bear and received a sticker after each electrode was placed on them in the presence of their caregiver). Participants then had their height and weight measured to capture children's physical size, calculated as body mass index (BMI), which has been posited as an important indicator of social dominance (Pellegrini et al., 2007). Room temperature was also measured at the beginning of the laboratory session to use as a possible covariate of physiological reactivity variables. Physiological measures were collected using Biolog ambulatory physiology recorders (UFI model 3991). A trained graduate research assistant placed skin conductance and electrocardiogram leads on the participating child who attended the laboratory physiological assessment. Once the leads were placed on the child, there was a 5-min accommodation period to allow participants to adjust to the physiological measures and to get the videos queued up for viewing.

Following the 5-min neutral video to collect baseline RSA and SCL, children then watched two additional 3-min videos (from *Sesame Street* episode 4265 and associated webisode, "Happy to be me: An anti-bullying discussion"). The first video depicted Big Bird being excluded from joining a "Good Birds club" that includes three birds. One bird yells and repeatedly excludes Big Bird for personal characteristics (e.g., "his feet are too big," "he is too tall," and "his feathers are too yellow"), despite Big Bird's attempts to have his friend, Abby Cadabby, change his appearance in response to the exclusion. The other two birds are bystanders that do not intervene. The second video showed adults and two characters from *Sesame Street*, including one of the bystanders, discussing the behaviors that constitute bullying and how to address bullying, as well as a resolution to the conflict with Big Bird and one of the bystanders.

RSA was assessed via electrocardiogram using a sampling rate of 1000 Hz. Disposable pediatric electrocardiogram electrodes were placed on participants' right and left rib in an axial configuration, with the ground lead affixed to participants' sternum. Cardiac inter-beat intervals (IBI) were measured as time in milliseconds between successive R waves of the electrocardiogram. Trained research assistants manually edited IBI artifacts due to movement or digitizing error in CardioEdit (Brain-Body Center, 2007). Next, CardioBatch, which uses a time-series moving 21-point detrending polynomial algorithm, was used to calculate RSA (see Porges, 1985). The frequency band-pass parameters used in the present study were 0.24 to 1.04 Hz to be consistent with spontaneous respiration in children. The mean RSA for each video segment was computed to yield a measure of RSA for each participant. RSA is reported in units of $\ln(\text{ms})^2$. A respiration belt was also placed around the participant's diaphragm in order to measure respiration as a possible covariate of RSA. The respiration belt sampled respiration at a rate of 10 Hz.

SCL was assessed using Ag/AgCl electrodes, which were attached to the distal phalanges of the first and second fingers of the child's nondominant hand. Participants were encouraged to wash and dry their hands prior to the session. A thin layer of an isotonic NaCl electrolyte gel was used on the electrodes to increase conduction, and adhesive collars were used to limit the gel to a 1 cm diameter circle on the participants' fingers. Skin conductance was measured in microsiemens.

SCLR and RSAR were calculated by subtracting the mean arousal during the baseline video from mean arousal during the exclusion clip and post-aggression discussion clip, respectively. Many studies examining SCLR and RSAR have used this approach (e.g., Beauchaine et al., 2013; El-Sheikh & Erath, 2011; Kalvin et al., 2016). For SCLR, positive values indicated increased SCL levels to the stimulus relative to baseline, whereas negative values indicated decreased SCL levels relative to baseline. For RSAR, negative values indicated decreased RSA to the stimulus relative to baseline, whereas positive values indicated increased RSA to the stimulus relative to baseline.

2.4 | Data analysis

Prior to running the primary path analyses, all continuous variables were winsorized to within three standard deviations (SDs) of the mean to decrease the influence of outliers (Kline, 2016). Predictors were also mean centered. In all path analyses, maximum likelihood with robust standard errors (MLR) was used in Mplus version 8.3 (Muthén & Muthén, 1998–2017) to accommodate variable skew. A likelihood ratio χ^2 test was used to test overall model fit where $p > .05$ indicates good model fit. The following fit indices were also considered: (a) comparative fit index (CFI), where values greater than 0.95 suggest good fit, (b) standardized root mean-square residual (SRMR) where values less than 0.08 represent mediocre fit, and values less than 0.05 indicate close fit, and (c) root mean square error of approximation (RMSEA), where values less than 0.08 suggest mediocre fit, and values less than 0.05 indicate close fit (Hu & Bentler, 1999).

We conducted a series of multigroup models with gender as the grouping variable to investigate gender differences in effects. For the concurrent models, T1 social dominance was regressed onto RSAR, SCLR, and their interaction for each video separately. BMI and room temperature were included as covariates. When Wald Chi-Square Tests of gender moderation were significant ($p < .05$) or marginally significant ($p < .10$), associations were freely estimated across groups; when associations were not moderated by gender, they were constrained to be equal across groups.

Within the longitudinal models, we first investigated gender differences in the stability of social dominance across the course of the study (i.e., T1 social dominance predicting T3 social dominance) and the influence of BMI over time. Room temperature was again tested as a possible covariate of SCLR, RSAR, and the interaction term. After imposing gender constraints in the stability model on parameters that did not differ by gender, we next added RSAR, SCLR, and their interaction to the model as predictors of T3 social dominance. As with the concurrent models, separate models were run for the exclusion and post-aggression discussion videos. Parameters that did not differ by gender were constrained to be equal across groups.

Across concurrent and longitudinal models, standardized and unstandardized estimates are reported for all terms, but only the unstandardized estimates were interpreted for terms that involve the interaction. If interactions were significant, they were probed at one SD above and below the mean of the moderator, to determine whether the effect of RSAR (predictor) was significant at various levels of SCLR (moderator).

3 | RESULTS

3.1 | Preliminary analyses

Descriptive statistics, including the number of participants who contributed data for each measure, are presented in Table 1. Children's T1 social dominance was rated following an average of 7.82 observations (SD = 0.59) and T3 social dominance on average of 7.55 observations (SD = 1.08). Descriptives indicated moderate levels of social dominance. Children also tended to exhibit an increase ($t_{exclusion}[79] = -5.30$, $p < .001$; Cohen's $d_{exclusion} = 0.27$; $t_{discussion}[79] = -8.19$, $p < .001$; Cohen's $d_{discussion} = 0.46$) in skin conductance from baseline ($M = 14.19$, SD = 7.87) to watching the exclusion ($M = 16.36$, SD = 8.40) and post-aggression discussion ($M = 18.19$, SD = 9.41) videos, and a decrease ($t_{exclusion}[77] = 2.24$, $p = .028$; Cohen's $d_{exclusion} = 0.10$; $t_{discussion}[77] = 3.69$, $p < .001$; Cohen's $d_{discussion} = 0.18$) in RSA from baseline ($M = 6.92$, SD = 1.28) to watching the exclusion ($M = 6.79$, SD = 1.37) and post-aggression discussion ($M = 6.67$, SD = 1.42) videos.

Missing data analyses indicated that children who participated in the physiological data collection generally did not differ from children who did not on demographics (e.g., gender, race/ethnicity, socioeconomic status) or key study variables (e.g., T1 and T3 social dominance).

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TABLE 1 Descriptive statistics and correlations of study variables

	N	Mean (SD)	Min–Max	Skew	1	2	3	4	5	6	7	8	9	10	11
1. Child age (months)	89	45.54 (3.81)	36.13–61.97	0.76	–										
2. Child gender	89	0.54	–	−0.16	−0.12	–									
3. Child race/ethnicity	88	0.30	–	0.91	−0.08	−0.16	–								
4. Child BMI	87	16.08 (1.49)	12.09–20.99	0.34	0.12	0.21^{+}	−0.30**	–							
5. T1 observation sessions	89	7.82 (0.59)	4.00–8.00	−4.57	−0.04	0.10	0.09	0.08	–						
6. T1 social dominance	88	17.26 (4.23)	8.00–29.00	0.29	0.07	−0.11	−0.15	−0.16	−0.08	–					
7. SCLR-Exclusion	80	2.13 (3.67)	−7.95–13.16	0.67	0.00	−0.03	0.01	−0.07	0.04	0.06	–				
8. RSAR-Exclusion	78	−0.13 (0.40)	−1.16–1.23	0.30	0.07	−0.17	−0.10	0.08	−0.24*	0.13	−0.05	–			
9. SCLR-Discussion	80	3.90 (4.21)	−3.77–17.15	0.93	−0.04	−0.03	−0.01	0.11	−0.18	0.07	0.60**	0.14	–		
10. RSAR-Discussion	78	−0.24 (0.53)	−1.90–1.42	−0.32	0.07	−0.03	−0.12	0.15	−0.17	0.24*	−0.10	0.64**	0.01	–	
11. T3 observation sessions	69	7.55 (1.08)	4.00–8.00	−2.42	0.18	0.13	0.03	0.01	−0.03	−0.05	0.01	−0.05	−0.04	−0.01	–
12. T3 social dominance	69	18.28 (4.81)	7.00–29.00	−0.05	0.04	−0.18	0.02	−0.03	0.11	0.23^{+}	−0.10	−0.04	−0.24	0.08	0.16

Note: Gender is coded: 0 = girls, 1 = boys; race/ethnicity is coded: 0 = White, 1 = non-White; observation sessions = number of times a child was observed before rating forms were completed.
Abbreviations: BMI, body mass index; RSAR, respiratory sinus arrhythmia reactivity; SCLR, skin conductance level reactivity; T1, Time 1; T3, Time 3.
$^{+}p < .10$, $^{*}p < .05$, $^{**}p < .01$; values represent post-winsorized data.

The one exception is that children who participated in physiological data collection tended to be older than children who did not ($p = .021$). This difference is in part due to a minimum age requirement for the laboratory visit including the physiological assessment; children had to be at least 48 months old to participate (Ostrov et al., 2022). Among the subsample used in the present analyses, further missing data analyses indicated that participants missing T3 social dominance data did not significantly differ from children with T3 social dominance data, nor did participants missing individual physiological reactivity data significantly differ from children with complete physiological reactivity data on key study variables.

Given debate in the field regarding whether respiration should be accounted for in studies of RSA (e.g., Laborde et al., 2017), we examined associations between RSAR and respiration at rest and during the two videos. As RSAR and respiration were not correlated, respiration was not controlled for in analyses. However, room temperature was included as a covariate of SCLR, RSAR and the SCLR x RSAR interaction term as it is correlated with the SCLR variables ($rs = 0.29$–0.60, $ps < .01$) and, unexpectedly, with girls' RSAR during the post-aggression discussion ($r = -0.43$, $p = .009$).

Finally, bivariate correlations were run to assess correlations between social dominance, aggression, and prosocial behavior at T1. Findings indicated that social dominance was positively associated with both aggressive ($r = 0.42$, $p < .001$) and prosocial behaviors ($r = 0.34$, $p = .005$); in addition, aggression was negatively related to prosocial behavior ($r = -0.25$, $p = .017$).

3.2 | Primary analyses

3.2.1 | Concurrent models

For the concurrent analyses, a multigroup path analysis with gender as the grouping variable was conducted to test whether associations between RSAR, SCLR, and their interaction, as well as BMI, in the prediction of T1 social dominance differed by gender. This model was run separately for physiological reactivity to each video. Within the exclusion model, Wald tests indicated that the covariance between RSAR-Exclusion and SCLR-Exclusion differed by gender [Wald $\Delta\chi^2(1) = 4.09$, $p = .04$], with girls trending toward a positive association and boys toward a negative one; all other pathways were constrained to be equal. The model provided a good fit to the data (see Table 2), but none of the predictors were significant ($ps = 0.35$–0.79).

Within the post-aggression discussion model, Wald tests indicated that the covariance between room temperature and RSAR-Discussion differed by gender [Wald $\Delta\chi^2(1) = 7.60$, $p = .006$], with a significant negative association for girls; all other pathways were constrained to be equal across groups. This model had good fit (see Table 2). For both boys and girls, RSAR-Discussion was positively associated with T1 social dominance (see Table 2). Neither the main effect of SCLR-Discussion ($p = .53$) nor the interaction between RSAR- and SCLR-Discussion ($p = .57$) were significant predictors of T1 social dominance.

TABLE 2 Regression parameters for predicting Time 1 social dominance

	Model			
	Social exclusion		Post-aggression discussion	
Predictor	*b*	*β*	*b*	*β*
BMI	−0.47+/−0.47+	−0.15/−0.17	−0.64*/−0.64*	−0.20/−0.24
RSAR	1.38/1.38	0.14/0.12	2.60*/2.60*	0.33/0.32
SCLR	0.03/0.03	0.03/0.03	0.06/0.06	0.05/0.06
RSAR × SCLR	−0.11/−0.11	−0.04/−0.03	−0.12/−0.12	−0.05/−0.07
	Fit statistics			
	χ^2 (16) = 11.98, p = .75 CFI = 1.00 RMSEA = 0.00 SRMR = 0.08		χ^2 (16) = 10.23, p = .85 CFI = 1.00 RMSEA = 0.00 SRMR = 0.07	

Note. Estimates show girls on left, boys on right.
Abbreviations: BMI, body mass index; CFI, comparative fit index; RMSEA, root mean square error of approximation; RSAR, respiratory sinus arrhythmia reactivity; SCLR, skin conductance level reactivity; SRMR, standardized root mean-square residual.
$^+p < .10$; $^*p < .05$.

3.2.2 | Longitudinal models

For the longitudinal analyses, a multigroup stability path analysis with gender as the grouping variable was conducted to test whether there were gender differences in the associations between BMI and T1 social dominance, respectively, and social dominance at T3; all parameters were freely estimated across gender in this initial model. The path from BMI to social dominance at T3 varied by gender [Wald $\Delta\chi^2(1) = 9.43$, $p = .002$], such that BMI was marginally related to higher T3 social dominance for girls and marginally related to lower T3 social dominance for boys (see Table 3). The path from T1 social dominance to T3 social dominance did not vary by gender.

To assess the longitudinal association between physiological reactivity to exclusion and social dominance, we fixed the parameters that did not differ across gender in the initial stability model to be equal for girls and boys, and added physiological reactivity at T1 as a predictor of T3 social dominance. That is, social dominance at T3 was regressed on BMI, T1 social dominance, RSAR-Exclusion, SCLR-Exclusion, and the interaction between RSAR and SCLR. This model provided good fit to the data (see Table 3). There were no gender differences in the associations between SCLR-Exclusion, RSAR-Exclusion, or their interaction in the prediction of social dominance at T3. The model in which parameters that did not differ by gender were constrained across groups provided a good fit to the data (see Table 3). However, no significant associations were found between SCLR-Exclusion, RSAR-Exclusion, or their interaction and T3 social dominance (ps = .18 to .90).

In a parallel model to assess longitudinal associations between physiological reactivity to post-aggression discussion and social dominance, social dominance at T3 was regressed on BMI, T1 social dominance, RSAR-Discussion, SCLR-Discussion, and the interaction between RSAR and SCLR. Gender moderation of the relations between SCLR-Discussion, RSAR-Discussion, and their interaction approached significance [Wald $\Delta\chi^2(3) = 6.88$, $p = .08$]. Therefore, these were freed across gender and the interaction was probed. Additionally, as in the concurrent model, gender moderation was found for the covariance between room temperature and RSAR-Discussion [Wald $\Delta\chi^2(1) = 7.72$, $p = .001$] with a significant negative association for girls. The model provided a good fit to the data (see Table 3). T1 social dominance was related to T3 social dominance for boys and girls, and there was a positive trend between BMI and T3 social dominance for girls (see Table 3). No other associations were significant for girls.

For boys, there was a negative relation between SCLR-Discussion and T3 social dominance and a negative relation between RSAR-Discussion and T3 social dominance (see Table 3). The interaction between SCLR-Discussion and RSAR-Discussion was also significant (see Table 3). At low levels of SCLR-Discussion, there was no relation between RSAR-Discussion and T3 social dominance ($b = -0.05$, SE = 1.34, $p = .97$; see Figure 1). At high levels of SCLR-Discussion, there was a negative relation between RSAR-Discussion and T3 social dominance ($b = -4.47$, SE = 1.56, $p = .004$).

3.2.3 | Robustness tests

Following the primary analyses, we ran follow-up analyses to test whether there were associations between RSAR, SCLR, and their interaction and social dominance above and beyond behaviors often used to achieve social dominance (i.e., aggression and prosocial behavior). That is, we ran the concurrent and longitudinal models controlling for T1 aggressive and prosocial behavior. Findings from the concurrent models indicated that the significant main effect of RSAR-Discussion on social dominance became marginal (p = .09). Within the longitudinal models, significant effects of associations between RSAR, SCLR, and their interaction in the prediction of boys' social dominance remained.

4 | DISCUSSION

The purpose of the present study was to investigate the interactive role of RSAR and SCLR in preschoolers' social dominance. We also

TABLE 3 Regression parameters for predicting growth in social dominance

	Model			
	Social exclusion model		**Post-aggression discussion model**	
	b	***β***	***b***	***β***
Concurrent associations				
BMI with T1 social dominance	*0.05/−1.62**	*0.01/−0.28*	*−0.11/−1.51**	*−0.02/−0.26*
RSAR with T1 social dominance	0.18/0.18	0.10/0.12	0.45/0.45	0.18/0.24
SCLR with T1 social dominance	1.78/1.78	0.11/0.12	2.10/2.10	0.11/0.12
Sympathetic nervous system activity in the hear				
RSAR × SCLR with T1 social dominance	−0.63/−0.63	−0.09/−0.17	−1.41/−1.41	−0.17/−0.15
Longitudinal associations				
T1 social dominance → T3 social dominance	0.23^{+}/0.23^{+}	0.21/0.21	0.25*/0.25*	0.23/0.23
BMI → T3 social dominance	**0.77^{+}/−0.63^{+}**	**0.23/−0.20**	**0.68^{+}/−0.51**	**0.20/−0.17**
RSAR → T3 social dominance	−1.26/−1.26	−0.11/−0.10	*1.62/−2.14**	*0.19/−0.23*
SCLR → T3 social dominance	−0.16/−0.16	−0.13/−0.12	*−0.06/−0.38**	*−0.06/−0.36*
RSAR × SCLR → T3 social dominance	0.05/0.05	0.02/0.01	*0.22/−0.58**	*0.09/−0.30*
	Fit statistics			
	χ^2 (21) = 13.40, p = .89 CFI = 1.00 RMSEA = 0.00 SRMR = 0.08		χ^2 (18) = 11.66, p = .86 CFI = 1.00 RMSEA = 0.00 SRMR = 0.07	

Note: Estimates show girls on left, boys on right. Italicized effects were marginally different across boys and girls ($p < .10$), whereas bolded values were significantly different across boys and girls ($p < .05$).
Abbreviations: BMI, body mass index; CFI, comparative fit index; RMSEA, root mean square error of approximation; RSAR, respiratory sinus arrhythmia reactivity; SCLR, skin conductance level reactivity; SRMR, standardized root mean-square residual.
$^{+}p < .10$; $^{*}p < .05$.

examined whether associations differed by the stimuli used to elicit autonomic nervous system reactivity (i.e., videos depicting exclusion vs. a post-aggression discussion) and child gender. We hypothesized that, relative to non-reciprocal ANS activation patterns, reciprocal patterns of ANS reactivity would be associated with children's ability to strategically establish and maintain social dominance. Exploratory analyses also investigated gender differences in these effects and whether effects held after controlling for prosocial and aggressive behavior, which are common behaviors used to achieve social dominance among preschoolers (Hawley, 2002).

Although we had hypothesized that non-reciprocal patterns of ANS activation would be associated with lower concurrent levels of social dominance, interactions between SCLR and RSAR in the prediction of concurrent social dominance were not significant. Instead, findings revealed a main effect of RSAR indicating that increased RSA activity to the post-aggression discussion video was positively associated with concurrent social dominance among both boys and girls. Some researchers have argued that decreased RSA activity in response to stress reflects greater emotion regulation capacities and better adjustment (see Graziano & Derefinko, 2013), yet others have argued that exaggerated RSA decreases to stress reflect emotion lability (Beauchaine et al., 2019). The implications of decreased RSA activity likely depend on the most appropriate behavioral response to the context. For instance, when the environment is relatively safe and adaptive responses require social engagement, RSA increases may support adaptive functioning because they facilitate a calm state (Hastings et al., 2008). Thus, in the context of viewing post-aggression discussions about victimization experiences, children exhibiting patterns of increased RSA activity may be able to adaptively engage with peers in ways that promote high levels of social dominance. It is important to note, however, that in our robustness test controlling for aggression and prosocial behavior, this main effect was no longer

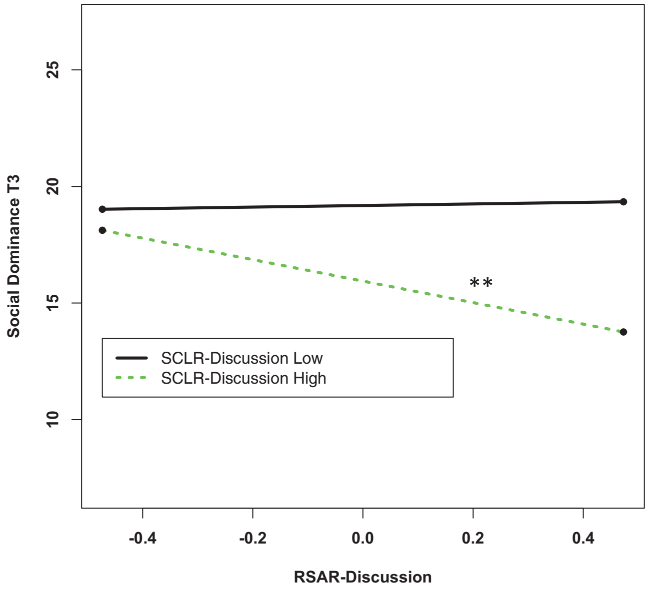

FIGURE 1 Interaction between SCLR-Discussion and RSAR-Discussion for boys. Body mass index (BMI) and social dominance at Time 1 which were centered and controlled for in the model. For girls there was not a significant two-way interaction between SCLR-Discussion and RSAR-Discussion. *Note*: $^{**}p < .01$, Abbreviations: Discussion, Post-aggression discussion; SCLR, Skin conductance level reactivity; RSAR, Respiratory sinus arrythmia reactivity; T3, Time 3

significant and therefore requires replication. Additionally, contrary to expectations, SCLR did not moderate associations between RSAR and T1 social dominance. As RSA activity is closely tied to emotion regulatory capacities (e.g., Graziano & Derefinko, 2013; Porges, 2007), findings support Hawley's (1999) suggestion that emotion regulation is a critical factor in children's social dominance and extend prior work to underscore the importance of physiological indices of emotion regulation in social dominance.

Longitudinal findings indicated that the interaction between RSAR and SCLR to the post-aggression discussion video was associated with boys' development of social dominance. As expected, both reciprocal patterns of autonomic nervous system reactivity (i.e., increased RSAR accompanied by decreased SCLR; decreased RSAR accompanied by increased SCLR) were related to moderately high levels of social dominance over time. In addition, boys who exhibited coactivation to the post-aggression discussion video exhibited especially low levels of social dominance at T3. El-Sheikh and Erath (2011) have argued that coactivation reflects dysregulated responses to conflict that are characterized by emotional lability, whereas reciprocal patterns are adaptive. Thus, adaptive autonomic nervous system functioning may support boys' capacity to effectively establish and maintain dominant positions in the peer group.

Interestingly, boys exhibiting coinhibition to the post-aggression discussion, indexed by increased RSAR accompanied by increased SCLR, had similar levels of social dominance at T3 as boys with both reciprocal patterns. This finding was unexpected, given prior research indicating that coinhibition increases risk for poor adjustment outcomes (e.g., externalizing problems) in the context of high-risk environments such as marital conflict (e.g., El-Sheikh et al., 2009; McKernan & Lucas-Thompson, 2018), although not all research finds that coinhibition is associated with adjustment difficulties, particularly in normative, low-risk samples (e.g., Keller & El-Sheikh, 2009; Murray-Close et al., 2017). One possibility is that boys who exhibit coinhibition are able to effectively gain dominance positions in the peer group because this pattern of physiological functioning supports manipulative approaches to social interactions. In fact, preliminary research documents associations between coinhibition to fear and callous-unemotional traits and deceitful manipulation (Thomson et al., 2019), which may facilitate children's capacity to achieve dominant positions at the expense of their peers. In another recent study by the same authors, men but not women who exhibited coinhibition in response to fear induction engaged in heightened levels of proactive aggression, and these proactively aggressive men reported feeling dominant during the task (Thomson et al., 2021). The authors speculate that coinhibition supports feelings of dominance in potentially threatening situations (Thomson et al., 2021). Thus, it is possible that coinhibition reflects emotional deficits and feelings of dominance that support boys' efforts to climb the social hierarchy, even when these efforts occur at the expense of peers.

The distinct patterns of effects across concurrent and longitudinal analyses may in part reflect differences in the physiological processes that facilitate the *establishment* versus *maintenance* of social dominance. In fact, Pellegrini and colleagues (2011) argue that social dominance hierarchies in preschool classrooms are established in the first half of the school year and correlates of social dominance in the spring reflect factors that underlie the maintenance of dominance. As a result, findings from the concurrent analyses in the present study suggest that increased RSA activity to the post-aggression discussion video may be especially important to the maintenance of social dominance. In prior research, affiliative behaviors, such as smiling at or talking with peers using positive affect, were especially strong predictors of preschoolers' social dominance during the spring (Pellegrini et al., 2011). Findings from the present study extend this prior behavioral work and highlight a potential physiological correlate of maintenance of social dominance. That is, RSA increases to the post-aggression discussion video, which is hypothesized to support calm social engagement in supportive contexts, may foster positive social interactions that help children maintain social dominance after hierarchies have been established.

Although social dominance at T3 was also assessed in the spring semester, the longitudinal design allowed for an investigation of how patterns of physiological reactivity predicted *changes* in dominance over time. Many children experienced transitions across the year that likely required renegotiation of social dominance positions, such as encountering new classrooms, new teachers, and changes in the composition of the peer group. Thus, longitudinal findings likely reflect both the *establishment* of social dominance across these transitions, as well as the *maintenance* of these new dominance positions over time. Pellegrini and colleagues (2011) argue that aggression and post-aggression reconciliation are strategies that preschoolers use to establish social dominance, whereas affiliation is used to both establish and maintain dominance. Findings from the present study extend this prior behavioral work by documenting patterns of physiological reactivity underlying the establishment and maintenance of boys' social dominance over time. Specifically, reciprocal patterns during depictions of affiliation and post-aggression reconciliation were associated with increases in social dominance over time. These physiological patterns may reflect well-regulated reactions to these social experiences. Further, coinhibition may foster callousness and feelings of dominance (Thomson et al., 2019, 2021) that promote efforts to climb the social hierarchy, even if these efforts occur at the expense of peers. Importantly, in the longitudinal analyses, the implications of RSAR depended on SCLR, bolstering calls among researchers to investigate how the PNS and SNS work together in children's development and adjustment (El-Sheikh et al., 2009).

Interestingly, autonomic reactivity to the post-aggression discussion, but not exclusion, was associated with social dominance concurrently and over time. These findings underscore the importance of the task used to elicit physiological responses in studies of developmental outcomes (Obradović et al., 2011). The findings also suggest that physiological regulation during post-aggression discussions may be especially important in preschoolers' capacity to establish and maintain socially dominant positions in the peer group. Notably, the behaviors depicted in the post-aggression discussion video, including providing support to the target of aggression, mirror behaviors used to manage the fallout of aggressive episodes, which have been linked to preschoolers' establishment of dominant positions with peers (Pellegrini et al., 2011). Thus, well-regulated physiological responses to these discussions may support social dominance.

Although tests of gender moderation were exploratory in nature, findings indicated that physiological reactivity to the post-aggression discussion video was associated with concurrent social dominance for both boys and girls but was only related to longitudinal changes in social dominance for boys. Specifically, for boys only, patterns of coactivation to post-aggression discussion predicted relatively low levels of social dominance over time. Although girls and boys tend to enjoy similar levels of social dominance overall (Hawley, 2002), there are some differences in their use of specific behavioral strategies, with boys being more likely than girls to use only coercive strategies and girls being more likely than boys to use only prosocial strategies (Hawley, 2014). Findings from the present study extend this prior behavioral research to suggest that there may also be distinct physiological correlates of social dominance in boys versus girls. Importantly, the post-aggression discussion video depicted discussion of an aggressive episode. Given the central role of coercive behaviors in boys' social dominance (Hawley, 2014), well-regulated physiological reactions to post-aggression reconciliation interactions may be especially important in the development of social dominance in boys. Future research may benefit from including physiological reactivity to depictions of prosocial exchanges (e.g., inviting a peer who looks sad to play with you), as well as discussions of prosocial interactions, as reactivity to these experiences may be especially important in understanding social dominance in girls. It is also possible that the analyses were underpowered to find statistically significant effects for girls. Future research is necessary to address these possibilities.

Importantly, robustness tests provided partial support for the suggestion that RSAR and SCLR are associated with social dominance above and beyond common behaviors related to dominance, such as aggression and prosocial behavior. In fact, the association between RSAR, SCLR, and their interaction in the longitudinal prediction of boys' social dominance held even when controlling for children's aggressive and prosocial behavior. Further, consistent with prior research (e.g., Ostrov & Guzzo, 2015; Pellegrini et al., 2011), correlations between social dominance and prosocial and aggressive behavior were moderate in size. These findings support the suggestion that social dominance is distinct from these behaviors, and highlight the importance of understanding processes, such as physiological regulation, that may facilitate children's ability to achieve socially dominant positions with peers. For instance, as some bullies may be dysregulated and rejected by peers whereas others may effectively use aggression to gain dominance and power (Hawley, 2015), autonomic regulation may provide insights into which children are able to effectively and strategically achieve and maintain social dominance, regardless of the specific behaviors that they employ. However, as the association between RSAR and social dominance dropped from significant to marginal in the robustness tests in the concurrent analyses, future research is needed in this area.

4.1 | Limitations and future directions

The present study has several strengths including the use of a longitudinal design with multiple methods and informants and the use of both observational and physiological approaches. Despite these strengths, there are several limitations that should be addressed in future research. First, although the sample size is similar to prior studies of this type (e.g., $N = 65$, Gower & Crick, 2011), the multi-group exploratory effects were likely underpowered. Indeed, our null findings within the three-way interaction of RSAR, SCLR, and gender may be due to low power. The findings await replication with a larger and more diverse (i.e., lower SES, more diverse race/ethnicity) sample. In addition, we did not assess the specific social dominance groups (e.g., bistrategic children) identified by Hawley (2003), and an important direction for future research will be to investigate patterns of physiological functioning in these groups.

Timing matters in developmental studies and in particular when examining the influence of social dominance. Indeed, Pellegrini and colleagues (2011) argue that different strategies are used to establish (i.e., aggressive strategies) versus maintain (i.e., affiliative strategies) social dominance in preschool classrooms and that the need to establish dominance will be highest across transitions (e.g., fall semester in a new school or classroom with a new peer group). This may suggest that different patterns of physiological reactivity predict social dominance in fall versus spring semesters of the school year. In the present study, both the concurrent and longitudinal measures of social dominance took place in the springtime, when classroom dominance hierarchies are generally already established. Future research should investigate correlates during the fall semester and across important transitions, such as the transition to kindergarten. Finally, future long-term longitudinal work is needed that cuts across developmental periods to assess whether similar physiological profiles relate to dominance across development.

Although examining the interaction of the SNS and PNS systems is a strength of this study, our measures investigated the influence of the SNS and PNS on different systems (i.e., PNS influences on the heart via RSAR; SNS influences on eccrine sweat glands via SCLR). RSA and SCL have been used in prior work investigating interactions between the PNS and SNS, including in the foundational research by El-Sheikh and colleagues (2009); nevertheless, measures of ANS activity can vary across target system and organs (e.g., Goedhart et al., 2008). An important direction for future social dominance research is to assess SNS and PNS activity within the same target organ or system (e.g., the cardiac system with RSAR and pre-ejection period, an SNS index of cardiac contractility; El-Sheikh & Erath, 2011).

5 | CONCLUSION

Despite these limitations, to our knowledge, no prior research has examined the role of RSAR, SCLR, and their interaction in preschoolers' social dominance. Findings highlight that the importance of RSA increases in boys' and girls' concurrent social dominance, providing support for the hypothesis that regulatory capacities play a role in classroom social dominance and that physiological markers can capture this critical process. Longitudinally, coactivation of RSAR and SCLR during post-aggression discussions predicted relatively low levels of social dominance in boys over time, extending prior work highlighting the importance of considering interactions across autonomic systems in studies of physiological correlates of children's social adjustment. The findings also underscore the significance of context for social dominance, namely, preschoolers' autonomic functioning following aggressive episodes. Practically, caregivers and teachers interested in promoting social dominance and resource control among preschool-aged children may wish to focus on teaching regulatory skills to children. Being able to remain calm after a difficult interaction with peers may be especially important, whereas children who are dysregulated in their reactivity may be at the highest risk of low social dominance over time.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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