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Journal
Social Cognitive and Affective Neuroscience, 16(11)

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Publication Date
2021-11-15

DOI
10.1093/scan/nsab065

Peer reviewed

Social Cognitive and Affective Neuroscience, 2021, 1150–1159

doi: https://doi.org/10.1093/scan/nsab065
Advance Access Publication Date: 27 May 2021
Original Manuscript

Collectivism is associated with enhanced neural response to socially salient errors among adolescents

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Abstract

The perceived salience of errors can be influenced by individual-level motivational factors. Specifically, those who endorse a high degree of collectivism, a cultural value that emphasizes prioritization of interpersonal relationships, may find errors occurring in a social context to be more aversive than individuals who endorse collectivism to a lesser degree, resulting in upregulation of a neural correlate of error-monitoring, the error-related negativity (ERN). This study aimed to identify cultural variation in neural response to errors occurring in a social context in a sample of diverse adolescents. It was predicted that greater collectivism would be associated with enhanced neural response to errors occurring as part of a team. Participants were 95 Latinx ($n = 35$), Asian American ($n = 20$) and non-Latinx White ($n = 40$) adolescents (ages 13–17) who completed a go/no-go task while continuous electroencephalogram was recorded. The task included social (team) and non-social (individual) conditions. ERN was quantified using mean amplitude measures. Regression models demonstrated that collectivism modulated neural response to errors occurring in a social context, an effect that was most robust for Latinx adolescents. Understanding cultural variation in neural sensitivity to social context could inform understanding of both normative and maladaptive processes associated with self-regulation.

Key words: collectivism; error-related negativity; social context; adolescent

Error monitoring is considered a critical aspect of self-regulation—it allows individuals to detect errors and alter behavior accordingly (Gehring *et al.*, 1993, 2012). Although adaptive processing of errors is a normative aspect of goal-directed behavior (Grammer *et al.*, 2018), errors can also be perceived as threatening (Weinberg *et al.*, 2012), eliciting aversion or distress (Spunt *et al.*, 2012). For example, individuals with internalizing disorders such as social anxiety are likely to experience a high degree of self-monitoring in response to internally generated fears (e.g. performance concerns and perceived evaluation) (Weinberg *et al.*, 2016; Meyer, 2017). However, there is considerable variability in the degree of threat sensitivity across

Received: 14 May 2020; **Revised:** 5 April 2021; **Accepted:** 3 May 2021

individuals. An error that occurs in a given context may be more meaningful depending on the beliefs and characteristics of a person (Weinberg *et al.*, 2012). Thus, factors such as an individual's cultural values and developmental stage could influence one's neural response to threat. As such, individuals who endorse greater prioritization of interpersonal relationships may view the consequences of errors that occur in a social context—for example, errors made while part of a team—as more catastrophic. The outcome of errors in a socially salient context may be perceived to be highly detrimental (e.g. disrupt group cohesion or rupture an interpersonal relationship). An individual with a high level of social threat sensitivity would be more motivated to prevent such experiences from occurring, resulting in greater self-monitoring to preempt socially-salient errors.

The error-related negativity (ERN or Ne), a neural correlate of error monitoring, is a sharp negative voltage deflection in the event-related brain potential (ERP) that peaks within 100 ms of an error response (Falkenstein *et al.*, 1991; Gehring *et al.*, 1993). Several theories exist regarding the functional significance of the ERN (Gehring *et al.*, 2012). Early theories suggested that the ERN reflects error detection, specifically a process in which an individual's response on a task is compared to the best approximation of the correct response (Falkenstein *et al.*, 1991; Gehring *et al.*, 1993). Within this framework, the process reflected in the ERN could be interpreted as part of an effort to use information about the presence of an error to make strategic adjustments that may prevent or correct the error (Gehring *et al.*, 1993; see also Holroyd and Coles, 2002). An alternative theory suggests that the signal reflects the presence of response conflict, with conflict detection leading to strategic adjustments (Botvinick *et al.*, 2001; Yeung *et al.*, 2004). Overall, the ERN can be considered to be an early evaluator signal that triggers a cascade of downstream processes (e.g. increased dorsolateral prefrontal cortex and amygdala activation; Kerns *et al.*, 2004; van Veen, 2006; Pourtois *et al.*, 2010) that then regulate subsequent emotional reactivity (Ullsperger *et al.*, 2008; King *et al.*, 2010; Danielmeier *et al.*, 2011).

Expanding on the error detection/comparator theory (Gehring *et al.*, 1993), as described above, is research that suggests that the ERN represents an affective response to errors (Luu and Pederson, 2004) and functionally reflects both cognitive and motivational factors (Shankman and Gorka, 2015). A number of investigations have supported this affective/motivational proposal and posit that the ERN is responsive to factors that influence motivation to prevent errors (Weinberg *et al.*, 2015), particularly given that the ERN is thought to represent the degree to which threat is internally generated (i.e. modulations are a result of what the individual perceives to be aversive/salient; Weinberg *et al.*, 2016). For example, experimental manipulations that enhance the value of errors (e.g. when errors are punished or incur monetary cost and when performance is evaluated) have been associated with increases in ERN magnitude (Hajcak *et al.*, 2005; Chiu and Deldin, 2007; Ganushchak and Schiller, 2008; Riesel *et al.*, 2012). Similarly, when manipulations are made to attenuate an individual's concern about errors (e.g. removal of a punishment), ERN magnitude decreases (Riesel *et al.*, 2012). Collectively, these studies suggest that contextual and dispositional factors influence the salience of errors, which is reflected in the ERN (Proudfit *et al.*, 2013).

Collectivism is one such dispositional factor that demonstrates an association with neural correlates of self-regulation. This cultural value is an attitudinal orientation that emphasizes connectedness with others, places a high value on harmonious interpersonal relationships and engenders a belief that individuals should be attentive to the unexpressed thoughts and feelings of others and adjust their behavior in response (Singelis, 1994). Certain racial/ethnic groups, particularly Latinx and Asian individuals, have been shown to endorse collectivism to a greater degree than their non-Latinx White (NLW) counterparts (Oyserman *et al.*, 2002). These groups have also demonstrated higher ratings of a related cultural construct, interdependent self-construal, which reflects the degree to which interpersonal relationships and social factors are included in an individual's perception of the self (Shweder and Bourne, 1984; Triandis, 1989; Markus and Kitayama, 1991). Sociocultural variation in endorsement of collectivism and interdependent self-construal are believed to be manifested at the neural level (Kitayama and Park, 2010; Kitayama and Uskul, 2011). These cultural constructs have been shown to modulate neural substrates of perception, attention and memory (Han and Northoff, 2008; Goh and Park, 2009; Ishii *et al.*, 2010; Han *et al.*, 2013), demonstrate associations with structural properties of the brain (Kitayama *et al.*, 2017) and executive functions (Medina *et al.*, 2019) and interact with genetic factors to influence behavioral outcomes (Way and Lieberman, 2010). Although less is known about the association of collectivism with neural systems related to threat perception, there is a small body of literature that has examined how interdependent self-construal influences neural correlates of self-regulatory processes using the electroencephalogram (EEG). For example, upregulation in error processing as a function of interdependence was detected when errors were committed in a social condition represented by affiliation (when earning points to win a prize for a friend) *vs* a non-social condition (when earning points to win a prize for oneself) (Kitayama and Park, 2014). In this study, European Americans showed a more negative ERN in the non-social condition than in the affiliation condition, whereas there was no difference in ERN between conditions for Asian and Asian American undergraduates. Further, interdependence was found to mediate the association of racial/ethnic group and the difference score between ERN in the self-condition and ERN in the friend condition. Face priming as a proxy for social context has also been shown to be associated with variability in ERN as a function of interdependence (Park and Kitayama, 2014). Although it is possible that these findings would generalize to other groups characterized by high levels of collectivism, the existing research is limited to samples of Asian and Asian American adults and NLW counterparts.

Adolescence may be a particularly important period for examining these associations, given the heightened salience of interpersonal relationships, particularly those with peers. There are developmental differences in motivational systems between adults and youth, which are posited to manifest in the ERN. In children and adolescents, social variables such as observation and evaluation have been found to enhance ERN (Kim *et al.*, 2005; Buzzell *et al.*, 2017), whereas nonsocial variables (e.g. monetary rewards) do not (Torpey *et al.*, 2009; Maruo *et al.*, 2017). More specifically, research has shown that manipulations of social context involving peer affiliation (e.g. observation or evaluation by a peer) result in enhanced ERN among adolescents (Buzzell *et al.*, 2017; Barker *et al.*, 2018).

The present study aimed to determine the association of collectivism with neural response to errors occurring in a socially salient context in a sample of racially/ethnically diverse adolescents. This was achieved through use of a go/no-go task that has been used extensively in youth samples (e.g. Grammer *et al.*, 2014; Moser *et al.*, 2018) and was adapted to include an ecologically valid manipulation of social context to tap the construct of collectivism, namely a team condition. Based on previous cultural and developmental research regarding ERN and the perceived salience of social context (Park and Kitayama, 2014; Buzzell *et al.*, 2017; Barker *et al.*, 2018), it was hypothesized that race/ethnicity would moderate the following proposed relations such that these associations would be more robust for Latinx and Asian American adolescents than for NLW adolescents: (I) higher scores on a self-report measure of collectivism would be associated with enhanced ERN in the team condition but not the individual condition (a negative association between collectivism and ERN_{Team} would be observed), and (II) higher collectivism scores would be associated with more differentiation between ERN in the team condition and ERN in the individual condition (i.e. a negative association between collectivism and $ERN_{Individual} - ERN_{Team}$ would be observed).

Method

Participants and procedures

A community sample of 113 adolescents (ages 13–17 years) was recruited from throughout Los Angeles as part of a larger study approved by the Institutional Review Board at the University of California, Los Angeles. Written parent consent and youth assent were obtained prior to initiating study procedures. Exclusion criteria were clinical-level elevation of attention-deficit/hyperactivity (ADHD) symptoms, IQ < 80, and parent-reported diagnosis of autism spectrum disorder. Eligibility was determined via administration of the Youth Self-Report (Achenbach, 1991), selection of subtests of the Wechsler Abbreviated Scales of Intelligence (Wechsler, 1999), and a brief review of youth psychiatric history with parent. After screening, six participants were excluded due to clinically elevated ADHD symptoms.

The remaining 107 participants completed three computerized EEG tasks. Eleven participants were excluded from analyses due to an insufficient number of error trials in one or both conditions. One participant appeared to be a statistical outlier based on inspection of several indices (e.g. standardized residuals, Cook's Distance and leverage). Following these exclusions, the final sample size of participants included in analyses was 95. Participants excluded from analyses did not differ from those included in terms of demographics or ratings of collectivism (analyses available upon request).

Sample size determination

A strong empirical basis is required to conduct an exact power analysis using a predetermined specific effect size (Miller and Yee, 2015), which was not available for the present study. Thus, we computed analyses for a medium and large effect size using the traditional recommendation of 0.80 for power at $\alpha = 0.05$. Taking into consideration our a priori regression-based data analytic plan, it was determined that a sample size of 74 would be adequately powered to detect medium effects. The present sample of 95 adolescents exceeded this estimate.

Measures

Demographics. Age, gender, race and ethnicity were collected via a standard demographic form. Parents provided an estimate of annual family income by selecting one of ten income ranges. Parents additionally reported how many individuals were supported by this income. Using this information, families were categorized as low income or not low income using guidelines from the U.S. Department of Housing and Urban Development.

Collectivism. Collectivism was measured using the Individualism-Collectivism Scale (Triandis and Gelfand, 1998), a 16-item measure. The measure was originally validated in a racially/ethnically heterogeneous sample of undergraduates and showed good internal consistency and convergence with other related measures of cultural values (Triandis and Gelfand, 1998). Previous research has demonstrated fair internal consistency of this measure in a sample of Latinx adolescents (Lorenzo-Blanco *et al.*, 2015). Internal consistency was good in the present sample ($\alpha = 0.81$).

Go/No-go task. Participants completed an adapted version of a developmentally appropriate go/no-go task (Grammer *et al.*, 2014). In this task, youth were told that they were playing a game in which the goal was to return escaped zoo animals to their cages and to avoid capturing friendly orangutans who are allowed to roam free at the zoo and do not need to be put into a cage. Youth were instructed to press a button as quickly as they could when they saw a zoo animal (go trials) and to inhibit response when they saw an orangutan (no-go trials). In half of the blocks, youth were told that points earned for correct responses went toward a team point goal, meaning that points accumulated in these rounds would be added to the score of a previous participant to reach a certain point goal. The team and individual conditions were introduced using the following text displayed on the computer screen and read out loud by the experimenter:

> Yesterday, another teenager like you came in and played this game. On some rounds of the game, you will be helping this person get to a certain number of points. On other rounds of the game, you will only be getting points for yourself. Before each round we will tell you if you are working toward the TEAM or INDIVIDUAL point goal. If you help yesterday's participant reach a certain number of points, you both win a prize. [*Experimenter would verbally say: 'The prize is a raffle ticket for you and the other teenager you are playing for to split a cash prize.'*] You can also win an additional prize if you get a certain number of points on your own. [*Experimenter would verbally say: 'The prize is a raffle ticket for an electronic device like an iPod Mini. If you win, you can keep the prize for yourself and you don't have to share it.'*]

Participants first completed a brief practice block of 12 trials, which included nine go trials and three no-go trials. Then, youth completed eight blocks of 40 trials which included 30 go trials and 10 no-go trials, for a total of 320 trials with the two conditions pseudo-randomly ordered. All of the go trial stimuli were novel and no-go stimuli were three images of similar looking orangutans. Blocks were evenly split between the individual and team conditions. Prior to a team condition block, the following text would be displayed on the computer screen and read out loud by the experimenter: 'On this round you will be helping the other teenager get points so that you both can win a prize. You are working toward reaching the TEAM point goal on this round.' For individual condition blocks, the following text would be displayed and read out loud by the experimenter: 'On this round you will be getting points just for yourself. You are working to reach the INDIVIDUAL point goal on this round.'

Participants were seated ~3 three feet away from a 23-inch LCD monitor on which the task was displayed using E-Prime software. Each trial began with a fixation cross presented for 300 ms followed by the stimulus presented for 500 ms. Stimuli were displayed 6.0 inch by 4.1 inch in size centered on the screen. A blank screen was then displayed for 500 ms. Youth were able to provide a response via button press on a game controller at any point while the stimulus or blank screen were displayed. Stimuli in each block were balanced with respect to color, animal type and size.

At the end of the experimental session, participants were informed that their points were not in reality being tallied throughout the game. They were told that they would still be entered into a raffle for a prize, with the winner selected at the end of data collection for the study.

Electrophysiological data recording and reduction

EEG recordings were obtained using a BioSemi ActiveView ActiveTwo system with an elastic cap containing 64 Ag/AgCl scalp electrodes. The electrooculogram was recorded by placing two electrodes near the outer canthi of both eyes and two electrodes above and below the right eye. Two electrodes were placed on left and right mastoids. Data were recorded referenced to a driven right leg passive electrode and common mode sense active electrode and re-referenced offline to that average of all head electrodes, in line with published recommendations (Dien, 2017). All impedances were maintained below 30 kΩ. Data were digitized at 1024 Hz with filters set to pass 0.16–100 Hz.

Data processing was conducted using Brain Vision Analyzer (Brain Products GmbH, Germany). Following an initial screen for extreme artifacts, the continuous EEG was segmented into 200 ms epochs. Epochs were inspected for gross artifact using an automated algorithm that rejected all channels in an epoch in which (i) the absolute difference between two adjacent sampling points exceeded 50 μV, (ii) the absolute voltage range across the epoch exceeded 300 μV, (iii) amplitude exceeded 150 μV or fell below −150 μV across the epoch and/or (iv) sustained activity less than 0.5 μV within a 100 ms interval had occurred. Ocular artifacts were corrected using the algorithm described by Makeig *et al.* (1996). Waveforms were filtered with a Butterworth zero phase 0.1–30 Hz bandpass filter.

In line with previous literature using youth samples, the ERN and correct-related negativity (CRN) were quantified using mean amplitude measures relative to a pre-response baseline of −300 to −100 ms prior to button-press that constituted an error. ERN mean amplitude was computed on error trials across the 100 ms following the button-press. The CRN was computed similarly but using correct trials. Because raw ERN measures include processes common to both errors and correct responses, a difference wave was computed by subtracting the EEG waveform on correct trials from the EEG waveform on error trials (i.e. ERN minus CRN), which highlights the ΔERN. The ΔERN is thought to be a more developmentally appropriate reflection of error-monitoring processes among youth (Torpey *et al.*, 2012; Grammer *et al.*, 2014) and was used as the dependent variable in all regression models. Given that there are several methodological choices that can be made when quantifying the ERN, the aforementioned methodological decisions were established a priori consistent with recommended guidelines (Luck and Gaspelin, 2017). Systematic examination of the impact of analytic strategies on the reliability of the ERN and the relationship of ERN with behavioral outcomes supports the use of a difference score approach and does not privilege any single set of methodological choices (Klawohn *et al.*, 2020). Participants with fewer than six error trials in a given condition after artifact screening were excluded, in line with previous research (Olvet and Hajcak, 2009a,b; Pontifex *et al.*, 2010; Foti *et al.*, 2013). Information on other complementary ERP components elicited by the task can be found in the Supplemental Materials.

Data analytic strategy

Repeated-measures Analysis of variance (ANOVAs) were used to confirm the presence of the ERN. Post-hoc analyses of significant interactions utilized paired samples *t*-tests. Group differences in ERN mean amplitude and difference score measures, as well as in reaction time and accuracy, were assessed using one-way ANOVAs. To test hypotheses that collectivism would be related to enhanced ERN in a social context and that this association would be moderated by race/ethnicity, three parallel linear regressions with ΔERN_{Team}, $\Delta ERN_{Individual}$ and $\Delta ERN_{Individual} - \Delta ERN_{Team}$ as the dependent variable were conducted to produce the conditional effect of collectivism on the ERP measure for each racial/ethnic group using the PROCESS Macro (Hayes, 2017) in SPSS 26. The PROCESS Macro provided an appropriate computational procedure for the present study, which hypothesized moderation of the association of collectivism and ERN by race/ethnicity, in that it calculated conditional effects and corresponding percentile-based bootstrap confidence intervals, as well as the proportion of variance uniquely attributable to the interaction (Hayes, 2012). All analyses were conducted using SPSS 26 except for effect sizes that were calculated using G*Power 3.1 (Faul *et al.*, 2009).

Results

Overall sample characteristics

Youth included in analyses were 50.5% male and 49.5% female with an average age of 15.13 years (s.d. = 1.34). The sample was comprised of Latinx ($n = 35$, 36.8%), Asian American ($n = 20$, 21.1%) and NLW ($n = 40$, 42.1%) adolescents. Based on 2018 guidelines for Los Angeles County from the U.S. Department of Housing and Urban Development, 33.7% of families were considered low-income using parent-reported annual family income and number of individuals in the household (81.2% of which were Latinx). The majority of youth in the sample were right handed (91.6%). The remaining youth were either left handed or ambidextrous.

One-way ANOVAs showed group differences in ratings of collectivism by race/ethnicity and low-income status, $F(2,92) = 7.39$, $P = 0.001$, $\eta_p^2 = 0.14$, $F(1,92) = 11.41$, $P = 0.001$, $\eta_p^2 = 0.20$. As anticipated, Latinx (M(s.d.) = 59.47(7.97); range = 37–70) adolescents endorsed more collectivism than NLW adolescents (M(s.d.) = 51.42(10.52); range = 28–70), Latinx *vs* NLW: $t(73) = -3.73$, $P < 0.0001$, $d = 0.87$. Asian American adolescents (M(s.d.) = 56.35(8.39); range = 39–68) did not significantly differ in collectivism ratings from NLW or Latinx adolescents. Low-income adolescents endorsed more collectivism than their respective counterparts.

There were no racial/ethnic group differences in gender distribution or age. However, there was a difference between racial/ethnic groups by low-income status, $\chi^2 = 40.58$, $df = 2$, $P < 0.0001$ such that low-income adolescents were predominately Latinx (81.2%). Race/ethnicity and low-income status were found to be strongly related, $\phi_c = 0.66$, $P < 0.0001$. However, these variables were not collinear, $M_{VIF} = 1.00$. Analyses

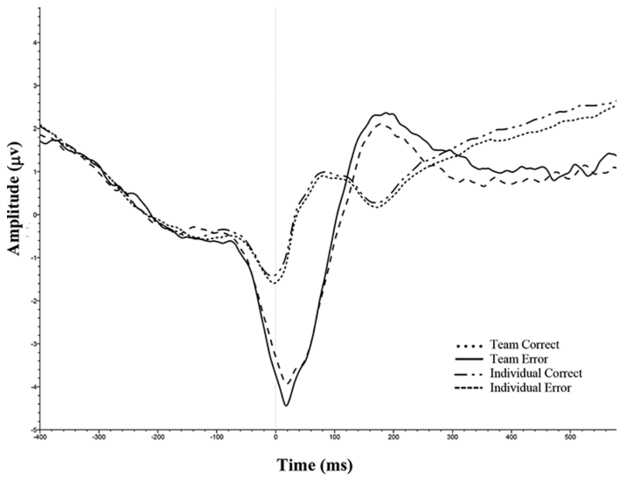

Fig. 1. Time course of neural response on error and correct trials at FCz recording site, relative to a baseline of 300–100 ms prior to error commission (at 0 ms), averaged across participants.

conducted with and without low-income status as a covariate produced similar results.

Confirming the presence of the ERN. As seen in Figure 1, visual inspection of grand-average ERP waveforms revealed an enhanced negative deflection around the time of error commission relative to correct response at frontal sites along the midline. The presence of an ERN was assessed using a repeated-measures ANOVA involving electrode site (FCz, Cz and Pz), response type (error, correct) and condition (team, individual). Mauchly's test indicated a violation of the assumption of sphericity; therefore, degrees of freedom were reported using Greenhouse–Geisser estimates. A site by response-type interaction indicated greater negativity of error trials relative to correct trials at frontocentral sites relative to parietal, $F(1.22,115.25) = 59.49$, $P < 0.0001$, $\eta_p{}^2 = 0.39$. Paired-samples *t*-tests showed that mean amplitude of the ERN at FCz in both team and individual conditions was more negative than at Cz, confirming that, as is typical, the ERN was maximal at FCz, team: $t(94) = -11.41$, $P < 0.0001$, $d = 0.97$; individual: $t(94) = -11.44$, $P < 0.0001$, $d = 1.08$. ERP measures in each condition varied as a function of site, $F(1.42,\ 133.46) = 3.91$, $P = 0.04$, $\eta_p{}^2 = 0.04$. The main effect of condition, the two-way interaction of response type and condition, and the three-way interaction of site, response type and condition were non-significant, P-values = 0.22–0.70. Response type and topographic results confirmed that the go/no-go task elicited an ERN as anticipated.

On average, 115.8 (s.d. = 6.9; range = 87–120) correct and 11.7 (s.d. = 4.1; range = 6–25) error trials were available after artifact correction in the team condition, and 116.5 (s.d. = 7.5; range = 70–120) correct and 12.6 (s.d. = 4.5; range = 6–28) error trials were available in the individual condition. There was no difference in number of trials following artifact correction between conditions for correct trials, $t(94) = -1.25$, $P = 0.21$, $d = -0.12$, although there were more errors trials following artifact correction on average in the individual condition than in the team condition, $t(94) = -2.21$, $P = 0.03$, $d = 0.19$. There were no racial/ethnic group differences, team correct: $F(2,92) = 1.71$, $P = 0.19$, $\eta_p{}^2 = 0.03$, team error: $F(2,92) = 0.09$, $P = 0.91$, $\eta_p{}^2 = 0.002$, individual correct: $F(2,92) = 0.36$, $P = 0.70$, $\eta_p{}^2 = 0.008$ and individual error: $F(2,92) = 0.83$, $P = 0.43$, $\eta_p{}^2 = 0.02$. Table 1 presents mean amplitude measures of ERP components. One-way ANOVAs and independent samples *t*-tests revealed no group differences in mean amplitude measures of ΔERN by race/ethnicity, team: $F(2,92) = 0.10$, $P = 0.91$, $\eta_p{}^2 = 0.002$, individual: $F(2,92) = 0.98$, $P = 0.38$, $\eta_p{}^2 = 0.02$; age, team: $t(93) = 0.25$, $P = 0.80$, $d = 0.05$, individual: $t(93) = 0.34$, $P = 0.73$, $d = 0.07$; gender, team: $t(93) = -1.2$, $P = 0.24$, $d = -0.24$, individual: $t(93) = -0.93$, $P = 0.35$, $d = -0.19$; or income, team: $t(92) = -0.72$, $P = 0.47$, $d = -0.16$ and individual: $t(92) = -0.38$, $P = 0.70$, $d = -0.08$.

Behavioral performance. Tables 2–3 present reaction time and accuracy on error and correct trials. Of note, two participants had missing task performance data due to a technical error during recording.

A repeated-measures ANOVA demonstrated that responses were faster on error trials than on correct trials, $F(1, 92) = 607.93$, $P < 0.0001$, $\eta^2 = 0.87$. Responses in the individual condition were faster than in the team condition, $F(1,\ 92) = 8.47$, $P = 0.005$, $\eta^2 = 0.084$, although this was only evident for correct trials, $t(92) = 3.64$, $P < 0.001$, $d = 1.56$. There were no racial/ethnic group differences in reaction time, team correct: $F(2,90) = 2.17$, $P = 0.12$, $\eta^2 = 0.04$, individual correct: $F(2,90) = 1.63$, $P = 0.20$, $\eta^2 = 0.03$, team error: $F(2,90) = 1.89$, $P = 0.16$, $\eta^2 = 0.04$ and individual error: $F(2,90) = 0.50$, $P = 0.61$, $\eta^2 = 0.01$. There were also no differences in accuracy by condition, $t(92) = -1.55$, $P = 0.12$, $d = -0.16$, or race/ethnicity, team: $F(2,90) = 0.23$. $P = 0.79$, $\eta^2 = 0.005$, individual: $F(2,90) = 0.81$, $P = 0.45$, $\eta^2 = 0.02$.

Collectivism and ERN in the team condition. In order to test whether the effect of collectivism on the ERN depended on social

Table 1. Mean amplitude values (μV) of ERN and CRN ERP components at FCz electrode site

		Full sample $n = 95$		NLW $n = 40$		Latinx $n = 35$		Asian American $n = 20$	
Condition	Component	M(s.d.)	Range	M(s.d.)	Range	M(s.d.)	Range	M(s.d.)	Range
Individual	CRN	−0.8 (1.6)	−5.7–2.3	−0.9 (1.7)	−5.7–2.11	−0.7 (1.6)	−5.5–2.3	−0.7 (1.5)	−4.0–1.6
	ERN	−2.9 (2.4)	−10.1–2.1	−2.6 (2.4)	−8.4–1.9	−3.1 (2.6)	−10.1–2.1	−3.0 (2.3)	−8.9–0.12
	ΔERN	−2.1 (2.4)	−9.8–2.9	−1.7 (2.6)	−9.7–2.9	−2.4 (2.3)	−9.8–2.0	−2.4 (1.9)	−6.4–0.47
Team	CRN	−0.9 (1.6)	−5.1–2.7	−0.9 (1.8)	−4.6–2.7	−0.8 (1.4)	−5.0–1.4	−0.9 (1.7)	−3.9–2.3
	ERN	−3.2 (2.7)	−10.9–2.9	−3.1 (2.5)	−9.7–2.7	−3.2 (2.7)	−10.9–1.2	−3.2 (3.0)	−10.9–2.92
	ΔERN	−2.2 (2.5)	−9.7–5.0	−2.1 (2.4)	−9.2–2.0	−2.4 (2.8)	−9.7–5.0	−2.3 (2.3)	−6.9–1.6

M = Mean; s.d. = standard deviation; NLW = Non-Latinx White; CRN = Correct-Related Negativity; ERN = Error-Related Negativity.

Table 2. Average reaction time by condition for error and correct trials

		Full sample M(s.d.) $n = 93$		NLW M(s.d.) $n = 39$		Latinx M(s.d.) $n = 34$		Asian American M(s.d.) $n = 20$	
Condition	Response	RT (ms)	Range	RT (ms)	Range	RT (ms)	Range	RT (ms)	Range
Team	Error	294.2 (29.9)	228.2–369.5	298.8 (28.2)	228.1–357.6	295.5 (27.6)	237.4–350.8	283.2 (35.1)	229.7–369.5
	Correct	328.4 (27.4)	273.2–410.6	331.5 (26.1)	273.2–404.2	331.3 (23.5)	276.8–378.0	317.2 (33.9)	275.1–410.6
Individual	Error	289.0 (29.2)	227.5–358.9	292.4 (31.0)	237.6–354.8	287.6 (24.0)	238.2–341.3	284.8 (34.0)	227.5–358.9
	Correct	323.8 (28.7)	257.8–417.2	326.7 (25.9)	272.3–378.9	326.5 (26.2)	275.9–379.8	313.6 (36.3)	257.9–417.2

M = Mean; RT = reaction time; ms = millisecond.

Table 3. Percent error on no-go trials by condition

	Full sample M(s.d.) $n = 93$		NLW M(s.d.) $n = 39$		Latinx M(s.d.) $n = 34$		Asian American M(s.d.) $n = 20$	
Condition	%	Range	%	Range	%	Range	%	Range
Team	30.5 (11.0)	12.5–67.5	31.4 (11.4)	15.0–67.5	29.7 (10.1)	17.5–57.5	30.0 (12.1)	12.5–55.0
Individual	31.9 (11.5)	15.0–70.0	32.7 (11.7)	15.0–65.0	32.7 (10.2)	15.0–70.0	29.0 (13.2)	15.0–60.0

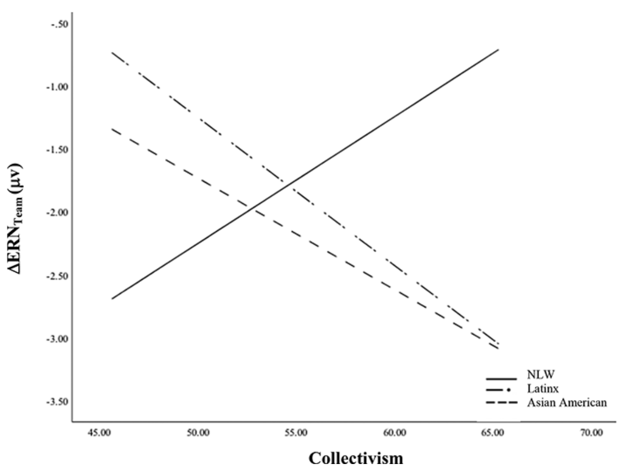

Fig. 2. Association of collectivism and ΔERN_{Team} for NLW, Latinx and Asian American adolescents. Larger negative values correspond to greater amounts of ΔERN_{Team}.

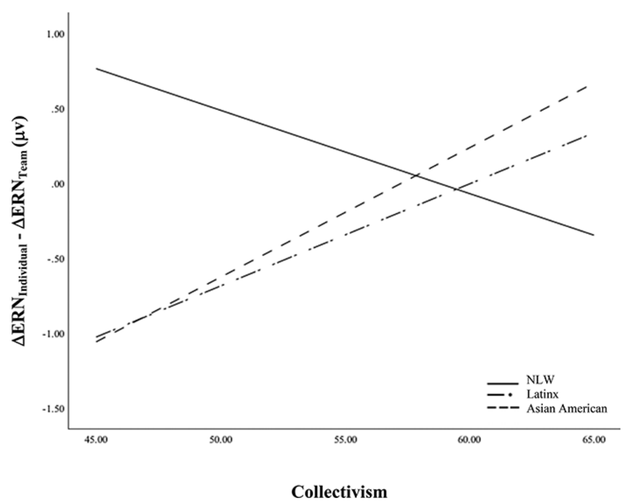

Fig. 3. Association of collectivism and $\Delta ERN_{Individual}$—ΔERN_{Team} for NLW, Latinx and Asian American adolescents. Larger positive values indicate enhanced ΔERN in the team condition relative to the individual condition.

environment, three parallel linear regressions were conducted using ΔERN_{Team}, $\Delta ERN_{Individual}$ and $\Delta ERN_{Individual} - \Delta ERN_{Team}$ as outcomes. Each model included collectivism as the predictor and race/ethnicity as a moderator, with age included as a covariate.

The first regression model tested the hypothesis that higher collectivism scores would be associated with enhanced ΔERN_{Team} (Hypothesis 1) and that this association would be more pronounced for Latinx and Asian American adolescents. The overall model accounted for 14.13% of the variance in ΔERN_{Team}, $F(6,88) = 2.41$, $P = 0.03$. Race/ethnicity interacted with collectivism in predicting ΔERN_{Team}, $F(2,88) = 7.07$, $P = 0.001$. Probing of this interaction revealed conditional effects illustrated in Figure 2 such that, as collectivism increased, NLW adolescents differentiated less between error and correct responses in the team condition and Latinx adolescents differentiated more, NLW: $\beta\alpha = 0.10$, $P = 0.009$, 95% CI = 0.02–0.17, Latinx: $\beta\alpha = -0.12$, $P = 0.02$, 95% CI = −0.22—-0.01. A conditional effect for Asian American adolescents was not observed, $\beta\alpha = -0.09$, $P = 0.18$, 95% CI = −0.22–0.04. This model provided support for the hypothesis that higher collectivism scores would be associated with enhanced ERN in the team condition and that this effect would be more pronounced for Latinx adolescents. However, results regarding the association between collectivism and attenuated ERN in the team condition for NLW adolescents were unanticipated. The second regression model, $R^2 = 0.04$, $F(6,88) = 0.72$, $P = 0.62$, confirmed that, as hypothesized, collectivism did not show an association with $\Delta ERN_{Individual}$, $\beta\alpha = 0.04$, $P = 0.23$, 95% CI = −0.03–0.12 (Hypothesis 1).

The final regression model tested the hypothesis that collectivism would be associated with a greater difference between ERN in the team condition and ERN in the individual condition (Hypothesis 2) and that this association would be moderated by race/ethnicity. The overall model accounted for 13.47%

of the variance in $\Delta ERN_{Individual} - \Delta ERN_{Team}$, $F(6,88) = 2.28$, $P = 0.04$. Race/ethnicity interacted with collectivism in predicting $\Delta ERN_{Individual} - \Delta ERN_{Team}$, $F(2,88) = 5.88$, $P = 0.004$. Conditional effects depicted in Figure 3 show that, for NLW adolescents, greater collectivism was associated with less differentiation between ERN in the team and ERN in the individual condition, $\beta = -0.05$, $P = 0.03$, 95% CI = −0.10 – −0.003. Conditional effects were detected for Latinx adolescents and were marginally significant for Asian American adolescents, suggesting greater differentiation as collectivism increased for adolescents from these cultural groups, Latinx: $\beta = 0.07$, $P = 0.05$, 95% CI = 0–0.14, Asian American: $\beta = 0.09$, $P = 0.06$, 95% CI = −0.004–0.17.

Discussion

The present study examined the interplay of individual differences in endorsement of cultural values with a psychophysiological measure of error monitoring. Collectivism was found to be associated with enhanced ΔERN in a social context as represented by a team condition, an effect that was most robust for Latinx adolescents. As anticipated, collectivism was differentially associated with ΔERN as a function of condition (team *vs* individual), suggesting that peer affiliation represented a motivationally significant context for adolescents (Buzzell *et al.*, 2017; Barker *et al.*, 2018). This association with neural response to errors did not necessarily correspond with behavioral performance on the go-no/go task, a common finding in studies of the ERN (e.g. Moran *et al.*, 2015; for review, Weinberg *et al.*, 2012). Behavioral responses on correct trials (i.e. a slight slowing of reaction time in the team condition relative to the individual condition) also did not appear to be reflected in CRN measures. In line with evidence that the ERN is reflective of the interaction of individual differences and contextual factors (Riesel *et al.*, 2012; Weinberg *et al.*, 2016), the present research also extended biopsychosocial models of social motivation (Blascovich & Tomaka, 1996; Blascovich *et al.*, 1999) in demonstrating that an individual's cultural views can influence the perceived value of the social context and, correspondingly, the motivational salience of errors occurring in a social context. These findings are consistent with other research that has examined the association of collectivism and related cultural constructs with neural processes related to goal-directed behavior. For example, individuals who were high in interdependence demonstrated less gray matter volume in the orbitofrontal cortex, suggesting lower self-interest when making decisions (Kitayama *et al.*, 2017). Considered together, these findings underscore that collectivism is related to early components of cognitive control, such as error-monitoring, as well as to higher order cognitive constructs like value-based decision-making.

Results suggest that cultural views related to prioritization of interpersonal relationships heighten the impact that social cues may have on neural correlates of error monitoring. Although the present study was motivated by prior work that showed a relation between collectivism and ERN in social contexts (e.g. when primed by a facial cue) among Asian and Asian American undergraduates (Kitayama and Park, 2014; Park and Kitayama, 2014), findings showed that this association was strongest for Latinx adolescents and only marginally detectable for Asian American adolescents. These results, together with the unexpected finding that collectivism was associated with attenuated ΔERN in the team condition for NLW adolescents, suggest that, although groups may share cultural views, the meaning of these values can vary due to experiences occurring at multiple levels, ranging from societal influences (e.g. economic downturn) to socialization practices (e.g. parenting) (Vargas and Kemmelmeier, 2013; Park *et al.*, 2014). Differential associations of collectivism with physiological outcomes serve as a reminder that cultural views and race/ethnicity should not be considered interchangeable or monolithic constructs, as each likely influences neural reactivity through distinct mechanisms (Gatzke-Kopp, 2016).

Findings can be further considered in relation to other research in adult samples that has examined ERN in socially motivational conditions. A range of experimental manipulations of social context have been used. Similar to the task design in the present study, adult participants were primed with statements challenging the existence of free will (i.e. determinism) and then asked to complete a flanker task to earn points for the benefit of either themselves or another person (Pfabigan *et al.*, 2020). Only those who were exposed to deterministic primes showed differences in ERN in self-relevant *vs* other-relevant conditions. A second study that included self *vs* other conditions produced similar results. On a flanker task, the effect of social context on ERN was not evident across the full sample, only for participants who were administered a nasal injection of oxytocin (de Bruijn *et al.*, 2017). Consistent with these studies, ERN amplitude in the present study was similar across team and individual conditions, meaning social and non-social contexts did not in and of themselves induce changes in ERN. However, when individual-level views (collectivism in the present study; induced deterministic thinking in research by Pfabigan and colleagues [2020]), variability in ERN amplitude emerged. Some studies have focused on socially relevant contexts such as cooperation and competition. ERN has been found to be enhanced when errors occurred in a competitive condition relative to a neutral condition (Van Meel and Van Heijningen, 2010), although evidence showing no such differentiation between conditions does exist (de Bruijn and von Rhein, 2012). As in other research (de Bruijn *et al.*, 2017; Pfabigan *et al.*, 2020), it is likely that individual-level factors that influence the significance of the competitive context play a role in determining to what degree the social context manipulation produces an effect on ERN (García Alanis *et al.*, 2019). Together, these studies reinforce endorsement of collectivism as a disposition that dynamically influences processing of certain situations (Fiske, 2002; Tamis-LeMonda *et al.*, 2008). That is, collectivistic values could represent what a given context activates and could also be reflected in a trait measure that predicts who is inclined to have such a perspective.

Limitations

This study has several strengths including a racially/ethnically diverse sample that includes participants from groups underrepresented in psychological science (e.g. Latinx and low-income individuals). Further, this study improved upon available research aimed at examining cultural variation in psychophysiological outcomes by measuring collectivism dimensionally, as much of the previous literature has inferred cultural views based on racial/ethnic group membership. However, results should be interpreted tentatively in light of some considerations. Specifically, the task used in the present study included an adapted component that has not been previously validated in a diverse sample, which limits the ability to determine to what extent methodological issues may have interfered with tests of conceptual associations. This adaptation also did not include having a peer physically present, as has been seen in other research examining the influence of social context on ERPs (e.g. Pfabigan *et al.*, 2020). Further, racial/ethnic groups were not matched on demographic variables, resulting in a notable imbalance between groups in terms of income distribution. Finally, at the end of study completion, participants were asked to indicate whether they were suspicious of any elements of the study. Six out of 107 adolescents endorsed some skepticism. However, to see whether this skepticism influenced performance, analyses were conducted with and without these participants, and results did not change.

Conclusions

The present study demonstrated that an adolescent's endorsement of collectivism influences neural correlates of social sensitivity during adolescence. Extant research on neural mechanisms of sensitivity to social factors in adolescence includes little attention to cultural processes (for review, Somerville, 2013), and further exploration of this intersection is an important next step for the field of developmental neuroscience (Fuligni *et al.*, 2018). Future research should examine longitudinal patterns of how collectivism influences neural response to threat given that both ERN and cultural views dynamically change throughout development (Davies *et al.*, 2004; Fuligni and Tsai, 2015). Other individual- and group-level constructs (e.g. socioeconomic strain, parenting practices), as well as task-related elements such as engagement, that may interact with collectivism to produce the effects observed in the present study warrant further research. Ultimately, clarifying culturally influenced trajectories of self-regulatory processes can inform understanding of how to promote adaptive development of key cognitive abilities as well as prevent the emergence of deleterious outcomes such as anxiety-related psychopathology.

Funding

This study was supported by a National Institute of Mental Health (NIMH) Ruth L. Kirschstein National Research Service Award Individual Predoctoral Fellowship (F31MH111187 to A.M.R.). A.M.R. was supported by a NIMH Institutional Training Grant (T32MH015144; PI: Steven Roose, M.D.) during preparation of the manuscript.

Conflict of interest

The authors declare no conflicts of interest.

Supplementary data

Supplementary data are available at *SCAN* online.

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