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BRIEF REPORT

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Sensitivity to facial expressions among extremely low birth weight survivors in their 30s

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The current study investigated the impact of birth weight on the ability to recognize facial expressions in adulthood among the longest known prospectively followed cohort of extremely low birth weight survivors (ELBW; <1,000 g). We measured perceptual threshold to detect subtle facial expressions and confusion among different emotion categories in order to disentangle visual perceptual ability from emotional processing. ELBW adults ($N = 64$, $M_{age} = 31.9$ years) were more likely than normal birth weight (NBW) controls ($N = 82$, $M_{age} = 32.5$ years) to see fear in angry faces. This finding was not a result of increased perceptual efficiency in processing fearful expressions in the ELBW adults, since the two groups did not differ on their threshold to detect emotion in low intensity facial expressions. These findings suggest that a processing bias toward fear may reflect long-term developmental effects from being born at ELBW that may portend socioemotional problems that characterize ELBW survivors.

KEYWORDS
adult, early life stress, extremely low birth weight, facial expressions, fear, infant, longitudinal

1 | INTRODUCTION

The ability to accurately infer other people's feelings from their facial expressions is essential for smooth and efficient social interactions. Even though children as young as age 5 can accurately recognize happy facial expressions, their accuracy for recognizing negative facial expressions continues to improve until early adolescence (De Sonneville et al., 2002; Durand, Gallay, Seig- neuric, Robichon, & Baudouin, 2007; Gao & Maurer, 2009, 2010; Kolb, Wilson, & Taylor, 1992; Herba & Phillips, 2004). Such a long developmental course leaves a wide time window for any adverse experience to affect the development of sensitivity to facial expressions.

One group in which this developmental process may be compromised is adult survivors of extremely low birth weight (ELBW; <1,000 g). Infants born at ELBW are exposed to suboptimal intrauterine conditions, which create extremely stressful pre- and post-natal environments. These infants spend their first weeks or months of life in the neonatal intensive care unit (NICU), where they require numerous painful invasive medical procedures and treat life-threatening conditions. This environment contrasts greatly from the generally non-threatening and protective intrauterine and early postnatal environment that term infants experience (Chau et al., 2014).

Longitudinal studies following ELBW survivors show that they are at increased risk for a range of physical, cognitive, social, and emotional problems later in life, even when exposed to a relatively typical post-natal environment after leaving the hospital. For example, compared to normal birth weight (NBW; birth weight ≥ 2,500 g) controls, survivors of ELBW have poorer general health, more neurosensory impairments, decreased intellectual performance, and increased mental health problems (Boyle et al., 2011; Levy-Shiff et al., 1994; Marlow, 2004; Mathewson et al., 2017; Rickards, Kelly, Doyle, & Callanan, 2001; Saigal et al., 1996; Saigal, Hoult, Streiner, Stoskopf, & Rosenbaum, 2000; Saigal, Rosenbaum, Szatmari, & Campbell, 1991; Saigal, Szatmari, Rosenbaum, Campbell, & King, 1990, 1991; Van Lieshout et al., 2015).

As young adults, ELBW survivors are characterized by shyness, timidity, behavioral inhibition, and risk aversion (Schmidt, Miskovic, Boyle, & Saigal, 2008; Waxman et al., 2013). As well, these survivors exhibit increased relative right frontal electroencephalogram (EEG) activity at rest (Schmidt, Miskovic, Boyle, & Saigal, 2010), a pattern that is associated with withdrawal, avoidance-related behavior, and intense responses to negative emotional stimuli (e.g., Davidson, 2000; Fox, 1991). Moreover, relative to NBW controls, ELBW survivors are at increased risk for developing psychopathology during adulthood, particularly anxiety, and depression (Boyle et al., 2011; Van Lieshout et al., 2015; see also Mathewson et al., 2017, for a recent systematic review).

Despite the crucial role of the ability to recognize facial expressions in social functioning, it is not known if ELBW adults have deficits in recognizing facial expressions. Recently, a growing body of research has demonstrated heightened vigilance to threat-related information, including threat-related faces, in individuals who exhibit disorders characterized by dysregulation of the fear system such as generalized anxiety (Egger et al., 2011), social anxiety (Miskovic & Schmidt, 2012; Tottenham et al., 2010), and behavioral inhibition (Perez-Edgar et al., 2010). Given that ELBW survivors share many characteristics with shy, anxious, and behaviorally inhibited individuals, we hypothesized that ELBW survivors, compared to NBW controls, would be more sensitive to facial expressions signaling threat (e.g., fear and anger).

Studies with children who grow up in atypical environments have demonstrated the importance of the post-natal environment in shaping children's ability to recognize facial expressions. For example, physically abused children, whose post-natal environment is characterized by abnormally high levels of exposure to anger, are more likely to detect angry facial expressions than typically developing children (Pollak & Sinha, 2002; Pollak, Cicchetti, Hornung, & Reed, 2000). Children subjected to neglect are more likely to have less exposure to facial expressions, and are less accurate at discriminating facial expressions than children reared in a normal social environment (Pollak et al., 2000). However, aside from atypical exposure to facial expressions, such environments are also marked by elevated levels of stress.

Here, we evaluated whether being born at extremely low birth weight might also interfere with the development of normal sensitivity to facial expression, particularly those signalling threat. Like neglected and abused children, exposure to perinatal stress contributes to atypical activation of the hypothalamic-pituitary-adrenal axis (Greenspan & Forsham, 1983). Specifically, we reasoned that the phenomenon of extremely low birth weight provides a natural experiment to assess the impact of very early life stress on the ability to recognize facial expressions in the absence of subsequent distorted exposure to facial expressions of the type experienced by neglected and abused children.

Atypical sensitivity to facial expressions could be manifested in at least two ways as demonstrated in previous studies examining children reared in atypical environments. The first is altered efficiency in using perceptual information to identify facial expressions. For example, physically abused children need less sensory input to recognize angry facial expressions (Pollak & Sinha, 2002). The second way is a response bias to facial expressions. For example, physically abused children have a bias to report angry facial expressions even when viewing sad faces or neutral faces (Pollak et al., 2000).

In the present study, we used a previously validated paradigm (Gao & Maurer, 2009, 2010; Gao, Chiesa, Maurer, & Schmidt, 2014), which provides separate measures for efficiency in using perceptual information to identify facial expressions, and for response bias among different facial expressions. More specifically, we measured: (i) a threshold level of intensity to detect emotions in faces; this measure gauges the efficiency in using perceptual information in emotional faces, and (ii) misidentification among different emotion categories; a measure of response biases among emotion categories.

With this paradigm, we compared a group of adults born at ELBW prospectively followed since birth and a matched NBW control group prospectively followed since early childhood on their sensitivity to facial expressions of fear, anger, and happiness in their early 30s. These facial expressions are salient signals of threats, warnings, and rewards, respectively, in the environment. To our knowledge, no studies have examined face processing in ELBW survivors in general and adults in particular. We predicted that ELBW adult survivors would show increased sensitivity to threat-related signals in the environment. Specifically, compared to NBW controls, ELBW survivors would have (i) a lower threshold to detect emotion in fearful and/or angry faces and (ii) a bias to report fearful and/or angry expressions.

2 | METHOD

2.1 | Participants

The extremely low birth weight (ELBW) cohort comprised 397 predominantly Caucasian infants (birth weight: 501–1,000 g; gestational age: 23–34 weeks) born between 1977 and 1982 to residents of a geographically-defined region in southern Ontario, and recruited at birth (see Saigal et al., 2006, 2016). Of these 397 infants, 179 (45%) survived to hospital discharge. There were 13 late deaths; therefore, 166 survived to adulthood. Adults who were born at ELBW were followed longitudinally from birth, and neurosensory impairments (e.g., cerebral palsy, blindness, deafness, mental retardation, microcephaly) were diagnosed by a neonatologist and a developmental pediatrician. We chose a homogeneous group of participants and therefore excluded individuals with neurosensory impairments, severe child-onset psychiatric problems, and those who were non-right handed (Oldfield, 1971). We selected only right-handed individuals because left-handed individuals are known to differ in the lateralization of emotion (Heller & Levy, 1981) as part of a larger study examining regional EEG asymmetry and emotion. One hundred ELBW survivors participated in the adult assessment (age 30–35). Of the 100, 64 had completed the facial emotion processing task in the present study (see Table 1 for a detailed description of the participants' demographic characteristics). The 64 ELBW participants did not differ from the original 166 ELBW survivors on either mean birth weight or mean gestational age (*ps* > .05).

The NBW control group was recruited when they and the ELBW cohort was 8 years old. This group comprised 145 individuals who were selected from a random sample of children born at term and obtained from class lists of 8-year-old children from the local public school board, and were matched with the ELBW sample on race, sex, and socioeconomic status (SES; Saigal, Rosenbaum, et al., 1991). Of the 145 NBW controls originally enrolled, 89 took part in the adult assessment. Of the 89, 82 had completed the facial emotion processing task in the present study. Despite the attrition, the current sample of the control participants did not differ from the ELBW participants on either SES (measured at age 8) or the highest level of education (*ps* > .05).

2.2 | Face processing task

2.2.1 | Affective face stimuli

We selected photographs of four models (two females), each posing facial expressions of happiness, fear, and anger, as well as a neutral expression from the NimStim face database (Tottenham et al., 2009). The images represent either no expression (neutral) or intense expressions of the designate emotions that had been recognized with high accuracy by adults in a previous validation study (Palermo & Coltheart, 2004). We created intermediate intensities of expressions by morphing each intense emotional face with its corresponding neutral face of the same model (see Gao & Maurer, 2009, for details). For each model and facial expression, we created 10 levels of intensity in 10% steps from 10% to 100% (see Figure 1a). In total, there were 124 expressions (3 expressions × 10 intensities × 4 models and 1 neutral expression × 4 models). The images were presented on a 22 inch color CRT monitor. From a viewing distance of 60 cm, each face subtended a viewing angle of 10.5° (width).

TABLE 1 Comparison of demographic information by birth weight group

Variable	ELBW	NBW
N (males, females)	64 (26, 38)	82 (31, 51)
Mean age in years (SD)	31.9 (1.6)	32.5 (1.4)
Birth weight in grams (SD)	834.2 (128.3)***	3384.4 (468.1)
Gestational age in weeks (SD)	27.2 (2.4)***	40 (0)
Mean highest level of education (SD)	5.49 (1.01)	5.47 (1.07)
Mean socioeconomic status at 8 years of age (SD) (Hollingshead, 1969)	3.05 (0.89)	3.04 (0.96)

***$p < 0.001$ compared with NBW participants. An education level of 5.5 is in between partial college and standard college.

2.2.2 | Procedures

Upon arrival, we described the study procedures to the participant and obtained written consent. The study protocol was cleared by the McMaster University Health Research Ethics Board. The procedure was based on our previous studies of normal development (Gao & Maurer, 2009, 2010) and was computerized. We first introduced four emotion icons representing happiness, fear, anger, and neutral to the participant. The emotions represented by the icons were accurately recognized by another group of adults in a previous study (Gao & Maurer, 2010). On each trial, a face was presented on the screen for 1 sec. After the face disappeared, the four emotion icons appeared on the screen until the participant pressed a pre-defined key to indicate his/her choice of emotion for the face in the current trial. One second after the key input, the next trial started. It took approximately 15 min to complete the experiment.

2.2.3 | Data analysis and measures

As in previous studies (Gao & Maurer, 2009, 2010; Gao et al., 2014), for each facial expression, we identified two types of errors: (i) failure to see any emotion in the face when the intensity was relatively low and (ii) misidentifying one facial expression as a wrong emotion category (e.g., misidentifying angry as fear). To measure these two types of sensitivity, we calculated (i) *threshold*, that is, the minimal intensity needed to detect any emotion in a face, a measure reflecting general visual perceptual ability and (ii) *misidentification rate* among emotion categories, a measure reflecting emotional response bias. We estimated the thresholds as the intensity level where an emotional face was equally likely to be classified as neutral or non-neutral (see Gao & Maurer, 2009, for details of the threshold calculation). Misidentification rate was calculated as the proportion of wrong responses out of the total number of non-neutral responses for each expression. For each measure, we averaged across the participant's independently derived scores for the four models.

2.2.4 | Young adult self-report (YASR; Achenbach, 1997)

Participants contemporaneously reported on socioemotional problems at the 30–35 age assessment using the Young Adult Self-Report

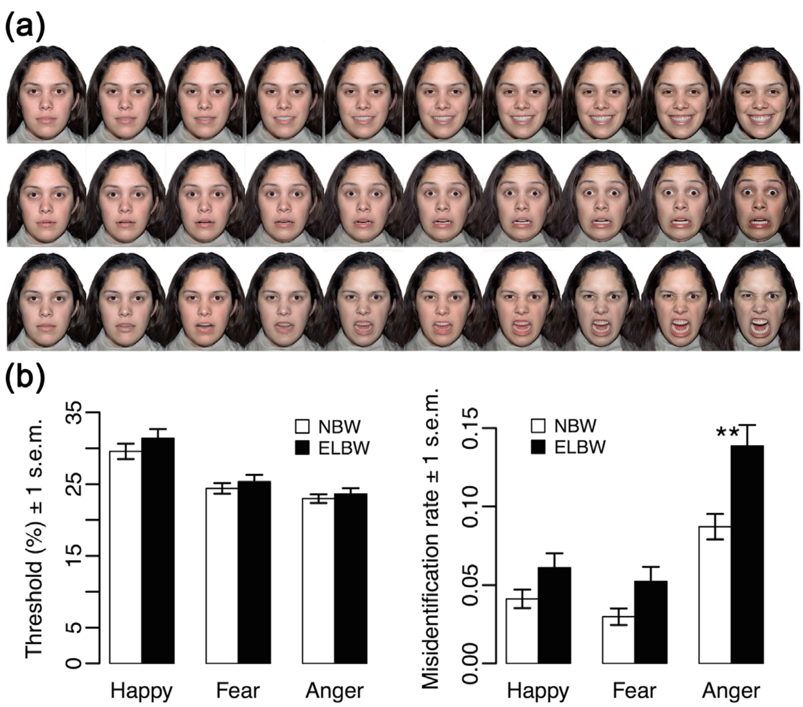

FIGURE 1 (a) Examples of facial expressions with varying intensities. Top to bottom rows: happiness, fear, and anger. Left to right, intensity levels of 10%, 20%, 30%, 40%, 50%, 60%, 70%, 80%, 90%, 100%. (b) Threshold and misidentification rate. *Threshold* (left panel): minimal intensity to detect a face as expressive. *Misidentification rate* (right panel): confusion of one emotion as other emotion categories. NBW, normal birth weight; ELBW, extremely low birth weight; ** $p < 0.01$

(YASR), a self-administered problem checklist (Achenbach, 1997). The YASR contains 130 problem items rated as: 0, not true; 1, somewhat or sometimes true; and 2, very true or often true. Here, we assessed the link between measures of emotion processing ability and the two broad band factors from the YASR: internalizing problems (alpha = 0.93) and externalizing problems (alpha = 0.85), as they reflect broad socioemotional problems, such as, depression/anxiety and aggression, respectively. Of the 64 ELBW participants in the current study, 62 had completed the YASR. Of the 82 NBW participants in the current study, 78 had completed the YASR.

3 | RESULTS

3.1 | Threshold

As shown in Figure 1b, the two groups did not differ in their thresholds to detect emotion in any of the three facial expression categories. This was supported by results from a mixed-model ANOVA with emotion category as a repeated measure and group (ELBW vs. NBW) as a between-subject variable. The main effect of group (F [1,140] = 1.62, $p = 0.20$, $\eta^2_p = 0.01$) and the interaction between emotion category and group (F [2, 280] = 0.56, $p = 0.53$, $\eta^2_p = 0.01$, Greenhouse-Geisser corrected) were not significant. This result suggests that the ELBW group was as sensitive as the NBW group in detecting low intensity emotion from faces expressing happy, fearful, and angry emotions, and that the two groups did not differ in their efficiency in using perceptual information to detect emotions in faces.

3.2 | Misidentification rates

The misidentification rates, however, revealed a different pattern from the threshold data (Figure 1b). A mixed-model ANOVA with emotion category as a repeated measure and group as a between-subject variable showed a significant main effect of group (F [1,140] = 10.27, $p < 0.01$, $\eta^2_p = 0.07$). The main effect of group was qualified by a significant interaction between group and emotion category (F [2, 280] = 3.73, $p = 0.028$, $\eta^2_p = 0.04$, Greenhouse-Geisser corrected).

To further probe this interaction, we ran three independent sample t-tests comparing the misidentification rates between the ELBW and NBW groups for each of the three emotion categories. For happy and fearful faces, the mean misidentification rates were low, and the two groups did not differ (happiness: t (105.3) = 1.72, $p = 0.09$, Cohen's $d = 0.30$; fear: t (109.6) = 1.74, $p = 0.09$, Cohen's $d = 0.30$; Welch corrected for unequal variance). For angry faces, the ELBW group had significantly higher misidentification rates than the NBW group (t [101.1] = 3.22, $p < 0.01$, Cohen's $d = 0.57$, Welch corrected for unequal variance). For both groups, angry faces were misidentified as showing fear in most of the cases of error. Out of all the angry faces that were reported as showing emotions (non-neutral), the ELBW group misidentified 12.2% of them as fear, while the NBW group only misidentified 7.4% of them as fear (t [90.44] = 3.60, $p < 0.01$, Cohen's $d = 0.65$, Welch corrected for unequal variance). The misidentification between anger and fear was not symmetrical. Out of all the fearful expressions that were reported as showing emotions, the ELBW group only misidentified 3.7% of them as anger, and this rate did not differ from the NBW group (2.4%, t [104.3] = 1.51, $p = 0.13$, Cohen's

$d = 0.27$, Welch corrected for unequal variance). Even though both the NBW group and the ELBW group showed a bias to report seeing fear in faces showing angry expressions, the bias was much higher in the ELBW group (a 65% increase relative to the NBW group).

3.3 | Associations of birth weight, face processing, and contemporaneous socioemotional problems

We assessed the relation between the face processing measures and contemporaneously reported socioemotional problems of the participants as well as birth weight. Consistent with the mean level group difference found in the misidentification rate for angry faces, birth weight was negatively correlated with misidentification rate for angry faces (r [138] = −0.256, $p = 0.012$, Bonferroni corrected for multiple tests), such that individuals with a lower birth weight were more likely to misidentify an angry face as showing other facial expressions (in the current case, fear). Consistent with previous reports with this cohort (see, e.g., Van Lieshout et al., 2015), the ELBW group had higher scores on internalizing problems in the YASR measure than the NBW group (ELBW mean = 15.0 ± 4.18, NBW mean = 11.8 ± 4.78, t [125.4] = 1.70, $p = 0.046$, *Cohen's* $d = 0.29$, one-tailed Welch t-test). The two groups did not differ in their scores on externalizing problems (t [142.1] = −0.33, $p = 0.74$, *Cohen's* $d = 0.05$). However, neither internalizing problems nor externalizing problems was associated with any of the face processing measures at the current assessment.

4 | DISCUSSION

In the current study, we found that adult ELBW survivors had a stronger bias to perceive fear than the NBW controls. As the ELBW survivors and the NBW controls did not differ in their threshold to detect emotion in subtle facial expressions of happiness, fear, and anger, it was unlikely that any general cognitive, perceptual, or attentional factors contributed to the increased fear bias observed in the ELBW survivors. However, when the emotion intensity was above their detection threshold, the ELBW survivors were more likely to report another negatively-valenced facial expression (i.e., anger) as showing fear. A similar bias for fear has been previously reported in behaviorally inhibited adolescents with lifetime anxiety disorders (Reeb-Sutherland et al., 2015). These adolescents showed a category boundary on the fear-angry continuum that was shifted toward the fear end relative to low behaviorally inhibited adolescents, or behaviorally inhibited adolescents without anxiety disorders. It has also been reported that adults with high trait social anxiety were more likely to classify an ambiguous facial expression as fear in fear-surprise and fear-sadness morph continua than the low trait social anxiety adults (Richards et al., 2002). In the current study, such a bias for fear was evident even though we restricted the ELBW sample to survivors without neurological or sensory impairments, that is, to a sample differing from the controls mainly in having experienced heightened stress in the perinatal period.

Both fear and anger are signals related to threat, but the sources of threat are different. While the angry face of another person is the direct source of threat, fearful faces of another person may indicate threat in the environment but the threat is indirect and uncertain and its source may or may not be known (e.g., Jetha, Zheng, Schmidt & Segalowitz, 2012). We found that ELBW survivors showed a bias to perceiving fear but not anger. Such a strong bias for fear in the ELBW group may reflect dysregulation of the fear system. As well, this pattern suggests the ELBW survivors may be hypervigilant to potential threat in the environment that is linked to uncertainty. Schmidt, Polak, and Spooner (2005) and Theall-Honey and Schmidt (2006) have suggested that the origins of shyness may be due to the inability to regulate fear.

Given that ELBW survivors have been characterized as shy, cautious, and anxious (Schmidt et al., 2008; Waxman et al., 2013), the present findings raise the possibility that ELBW individuals are hypervigilant to perceiving emotional signals in the environment, especially for emotions signaling threat. However, few studies have attempted to examine possible mechanisms underlying these behavioral phenotypes. It is possible that the fear bias observed in ELBW survivors might be a putative mechanism underlying a shyness phenotype often observed in this population (e.g., Schmidt et al., 2008; Waxman et al., 2013).

Previous studies with children reared in atypical environments have shown that children growing up in stressful environments with distorted exposure to facial expressions have altered perception of facial expressions (Pollak & Sinha, 2002; Pollak et al., 2000). Even though the source of stress experienced by ELBW survivors differs from that of either physically abused or neglected children, these different types of stress may involve similar physiological processes and consequences for some aspects of face processing. Here, we found that ELBW survivors have a strong bias to report fear without increased efficiency in processing perceptual information in fearful faces. This differs from findings with physically abused children, where both a bias to report anger and an increased efficiency in processing perceptual information in angry faces were found (Pollak & Sinha, 2002). We suspect that the increased efficiency in processing perceptual information in emotional angry faces in abused children depends on perceptual learning from unusual exposure to angry faces, which they, but not the ELBW group would experience, and not just a stressful upbringing. On the other hand, the relation between different types of stress and their outcomes would require further investigation.

The current data cannot explain the underlying mechanism for the response bias for fear in the ELBW group. It is possible that the abnormal perception of angry facial expressions in the ELBW group might underlie the shy and anxious personality profile that is typically seen in this group. It is also possible that the altered perception of facial expressions may contribute to the development of psychopathology symptoms that the ELBW group often displays. Although in the current sample the ELBW group had higher internalizing problems than the NBW group, we did not find relations between face processing and contemporaneous measures of socioemotional problems. It may require future longitudinal research with a larger sample to examine whether ELBW survivors' increased bias to perceive threat plays a role in predicting the prospective development of psychopathology.

Future studies could also examine commonalities and differences in the way perinatal and postnatal stress from ELBW versus abuse or neglect, respectively, affect the development of sensitivity to facial expressions.

The current study was limited by its relatively small sample size, which limits an investigation of the relation between the ability to process facial expressions and other neuropsychological characteristics of ELBW survivors. Nevertheless, with the current sample, we were able to show a group differences in processing facial expressions. Even though the current ELBW sample has been longitudinally followed, we only tested their ability in processing facial expressions at a single time point in adulthood (30–35 years old). The adulthood measures of face processing ability would have limited predictive value for subsequent psychopathology, as one would expect less developmental changes in the current sample in comparison to a child or adolescent sample. Therefore, it would be more informative to test such ability at earlier ages and over time to provide a better picture of the developmental course of the phenomenon. It would also be informative to extend the testing to other negative facial expressions, namely sad expressions, which are perceived abnormally by neglected children and fundamental for social expressions of empathy, and expressions of disgust, for which no differences would be expected. Finally, the current sample of ELBW survivors was born in the 1980s. Over the past 30 years, neonatal intensive care practices have been improved significantly with advances in medical research and technology, so it would be important to test more recent cohorts of ELBW survivors to replicate our findings.

In conclusion, the present study provides the first known empirical evidence that pre- and early post-natal stress from being born at extremely low birth weight alone may be sufficient to impact the perception of facial expressions in a long-lasting way. Indeed, these perinatal exposures may affect the neural structures necessary for accurately decoding negative facial expressions and may contribute to the increased rates of socioemotional problems observed in ELBW survivors. However, the influence is also likely to be bidirectional with those problems impacting the ability to identify facial expressions.

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CONFLICTS OF INTEREST

The authors declare no conflicts of interest.

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