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Birth Weight and Social Trust in Adulthood

**Birth Weight and Social Trust in Adulthood:
Evidence for Early Calibration of Social Cognition**

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Abstract

Social trust forms the fundamental basis for social interaction within societies. Understanding the cognitive architecture of trust and the roots of individual differences in trust is of key importance. We predicted that one of the factors calibrating individual levels of trust is the intrauterine flow of nutrients from mother to child as indexed by birth weight. Birth weight forecasts both the future external environment and the internal condition of the individual in multiple ways relevant for social cognition. Specifically, we predicted that low birth weight is utilized as a forecast of a harsh environment, vulnerable condition, or both and, consequently, reduces social trust. The results of the study reported here are consistent with this prediction. Controlling for many confounds through sibling and panel designs, we found that low birth weight reduced social trust in adulthood. Furthermore, we obtained tentative evidence that this effect is mitigated if adult environments do not induce stress.

Keywords: birth weight, social trust, stress, life-history strategies, evolutionary psychology

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One key individual difference in human social cognition is the difference in the propensity to trust other individuals. Because of the selection pressures guiding the evolution of cooperation and its underlying psychology (Trivers, 1971), trust is a psychological necessity for the formation of cooperative relationships among non-kin (Ostrom, 2000, p. 144). Accordingly, individual differences in social trust predict a range of social behaviors related to cooperativeness, including charity work, tax contributions, democratic behavior, electoral participation, and recycling (Svendsen & Svendsen, 2009). People with high levels of trust are essentially “‘all-around’ good citizens” (Putnam, 2000, p. 137).

Psychologically, the act of trusting others represents an exercise in delayed gratification. Investing in others—in community and society—requires a motivation to pay costs in the present in order to reap future benefits (Michaelson, de la Vega, Chatham, & Munakata, 2013; Trivers, 1971). Research shows that such motivations are components of larger clusters of dispositions referred to as life-history strategies. People’s life-history strategies, across domains of life, fall on a continuum from fast to slow: For example, early sexual maturity, relatively rapid physical development, reduced parenting efforts, and increased risk taking related to finances and crime go together in a fast strategy (Del Giudice & Belsky, 2011; Ellis, Figueredo, Brumbach, & Schlomer, 2009; Figueredo et al., 2006). In understanding the factors giving rise to an individual’s life-history strategy, researchers emphasize the role of early childhood experiences (e.g., Griskevicius et al., 2013; Simpson, Griskevicius, Kuo, Sung, & Collins, 2012) and even intrauterine factors, as indexed by birth weight (Frederick, 2012; Nettle, Coall, & Dickins, 2010). Extending these findings, we investigated whether individual differences in birth weight are associated with differences in trust in adulthood.

In emphasizing birth weight, a biological variable, we parted with the emphasis on social and economic factors that is traditional in social science. In research on early determinants of trust, family socialization and childhood socioeconomic status have been assumed to be key (e.g., Uslaner, 2002). To gauge how widespread such assumptions are, we contacted researchers in sociology, economics, and health research at a large Danish research university, asking them to evaluate the relative importance of three potential early determinants of social trust. Two of these were traditional socioeconomic factors: mother's income and mother's education. The third factor was birth weight. More than 100 researchers replied (see Supplemental Methods and Results in the Supplemental Material available online). Ratings of relative importance were recoded on a scale from 0 to 1, such that the ratings of the three factors added up to 1. Across disciplines, the researchers intuitively evaluated the traditional socioeconomic factors, particularly mother's education, as most important (mean rating = .57 for mother's education and .26 for mother's income). As expected given the neglect of biological factors in attempts to understand social outcomes, birth weight was rated as having less than one fourth of the combined importance of the socioeconomic factors (mean rating = .18).

Birth weight, however, is a function of multiple factors serving as potential input to psychological systems for calibrating trust. First, birth weight is influenced by both the mother's access to nutritional resources (Ramakrishnan, 2004) and her investment of these resources in her fetus (Del Giudice & Belsky, 2011; Fessler, Navarrete, Hopkins, & Izard, 2005; Figueredo et al., 2005). The degree of such investment is partly regulated by the mother's social environment (e.g., Buka, Brennan, Rich-Edwards, Raudenbush, & Earls, 2003; Feldman, Dunkel-Schetter, Sandman, & Wadhwa, 2000; Kramer, 1987). A lack of social support prompts reproductive bet hedging, whereby the mother reduces her pre- and postnatal investments in each offspring in

favor of having more offspring (Fessler et al., 2005; Haig, 1996; Wells, 2003). From the fetus's perspective, these associations imply that limited nutrient flow forecasts a future environment with scarce resources, inadequate social support, lack of parental care, or a combination of these characteristics. In such environments, an organism that delays rewards—and trusts others to do the same—is at a fitness disadvantage (Figueredo, Andrzejczak, Jones, Smith-Castro, & Montero, 2011; Figueredo et al., 2006). To the extent these environmental features were relatively stable across the life cycle of ancestral individuals, such associations between intrauterine dynamics and social environments could have selected for fetal mechanisms designed to utilize these dynamics to adaptively calibrate social cognition over development (e.g., by investing more developmental resources in the neurological machinery required for trust; see Petersen, Roepstorff, & Serritzlew, 2009).

Second, an individual's birth weight is also influenced by stochastic processes related to, for example, the insertion of the umbilical cord into the placenta (Yampolsky et al., 2009). These processes do not necessarily track the external environment of the fetus but can potentially be utilized for the calibration of social cognition because of their forecasted effects on the future internal state of the individual (Jones, 2005; Nettle, Frankenhuys, & Rickard, 2013). Individuals with lower birth-weight are generally smaller throughout life (Sørensen et al., 1997) and are more likely to suffer a variety of negative health outcomes (Barker, Eriksson, Forsen, & Osmond, 2002). To “make the best” (see Jones, 2005) of these forecasted adverse states, an adaptive response for low-birth-weight individuals would be to develop a phenotype that reaps benefits promptly so that those benefits can be harvested while the individuals are alive. These stochastic intrauterine processes can shape adult levels of trust as an incidental by-product of their general effects on life-history strategies.¹ An effect on trust is also possibly adaptive in

itself. Research suggests that people in adverse states resulting from small size and physical vulnerability are likely objects of social exploitation (Sell, Tooby, & Cosmides, 2009). Low birth weight might therefore forecast an increased likelihood of future exploitation, possibly providing the basis for a selection pressure for the evolution of a relevant calibrational mechanism.

These observations suggest that at least two pathways could adaptively link birth weight and social trust such that lower birth weight leads to lower social trust. Mechanisms in the fetus could use limited nutritional flows to forecast (a) a future harsh material or social environment or (b) future physical vulnerability. As a consequence of one or both forecasts, dispositional tendencies for social trust in low-birth-weight individuals could be downregulated.

Study 1: Does Birth Weight Predict Social Trust in Adults?

Study 1 was a first test of the effects of birth weight on social trust in adulthood. We used a sample that allowed us to obtain an objective measure of birth weight directly from medical records and relied on a powerful tool for causal inference: a sibling design (cf. Donovan & Susser, 2011, p. 345).

Method

Our data were taken from the Danish government registries about all persons living in Denmark. Card, Chetty, Feldstein, and Saez (2011) emphasized that administrative data are “critical for cutting-edge empirical research” (p. 1), and Denmark has “one of the world’s most comprehensive registrations of its citizens’ use of medical and social services” (Hallas, 2001, p. 619). A vital feature of these data is that they are based not on self-report but on high-quality official, administrative records (Kreiner, Lassen, & Leth-Petersen, 2013). Through the Centre for

Survey and Survey/Register Data, we were provided access to the Danish government registries. Using the registries, we linked official hospital records on birth weight for people born in Denmark to responses in five rounds of the European Social Survey (ESS) from 2002 to 2010. These particular surveys included a measure of social trust. Furthermore, we were able to obtain official records of the socioeconomic status of the family heads at the birth of the target individuals and (in most cases) the birth weight of one or more of the target's siblings. Overall, by integrating register data with the ESS data, we obtained high-quality information on birth weight and key variables (i.e., data with minimal measurement error and no self-report or social-desirability biases), which increased our leverage for testing a causal relationship.

The ESS is administered to a random and representative probability sample of Danish citizens over age 15 (for detailed descriptions of sampling decisions, see ESS, 2012). We had complete birth-weight data ($M = 3318$ grams, $SD = 595$ g) for 1,664 ESS respondents born after the late 1970s, when the government registries began recording birth-weight information. The key analysis was based on a total of 1,554 respondents with complete data on all central measures (Sample 1; see Supplemental Methods and Analyses for additional details on this sample and the measures included in our analyses). In addition, we were able to form two subsamples with sibling information: (a) a subsample of 1,214 respondents consisting of all individuals with a sibling for whom the registry included birth weight information and (b) a smaller sample of 447 respondents for whom we have available not only the birth weight of the closest younger sibling but also more detailed information about that sibling's gender and age.

As noted, our measure of social trust came from the ESS. Specifically, we utilized the international-standard measure of social trust that is also used in the World Values Study/European Values Study and the General Social Survey (e.g., Inglehart & Welzel, 2005, p.

22; Knack & Keefer, 1997, p. 1256; Uslaner, 2002, p. 52). Respondents were asked whether they believed that a person cannot be too careful when dealing with other individuals or that most people can be trusted and responded on an 11-point scale (after responses were recoded on a scale from 0 to 1, $M = .67$, $SD = .17$; higher values indicate greater trust).² For control variables, we used respondents' gender and birth year, taken from the ESS data set. We were also able to utilize the registry data to obtain precise, objective measures of the socioeconomic status of respondents' family heads (by default, respondents' mothers). Specifically, we constructed measures of the mothers' income and education.

Finally, we obtained the birth weights for one or more siblings when this information was available. This variable allowed us to utilize a sibling design to estimate the causal effect of an individual's birth weight with substantial precision. Two key confounding variables for any study of birth weight are family environment and genetics. Sibling data, however, allow researchers to address these confounds to a significant extent (see Donovan & Susser, 2011). Siblings share the same family environment to a large degree and, on average, share 50% of their genes. Consequently, if the family environment or genes confound the effect of birth weight on social trust to a significant extent, a sibling's birth weight should be just as sizable a predictor or 50% as sizable a predictor, respectively, as the target individual's birth weight. In contrast, if a sibling's birth weight is unrelated to the target's social trust and the effect of the target's birth weight is unchanged when the analysis controls for a sibling's birth weight, the evidence supports the conclusion that the effects of birth weight causally reflect experiences unique to the target (e.g., the intrauterine environment).

Donovan and Susser (2011) noted that study designs exploiting the fact that siblings share stable aspects of family environment and half of their genes are "particularly suitable for examining the

relation of prenatal exposures to offspring outcomes” (p. 346). At the same time, it must be noted that a sibling design is not a true experimental design; it is vulnerable to two particular confounds: The first is changes in family environments that affect one child but not others. To address this confound, we created two subsamples with sibling data. Whereas the larger one had more statistical power, the smaller one included information about siblings’ age and gender. A sibling’s birth weight is presumably a better proxy for confounds in the shared environment to the extent that the target and sibling are of the same gender and close in age. We also controlled directly for key measures of family environment using the measures of parental socioeconomic status. The second potential confound is genes that simultaneously and directly influence both birth weight and social trust. In principle, we could not rule out this latter confound; in practice, however, the existence of such genes has yet to be demonstrated.

In the analysis, all the measures were rescaled to vary between 0 (lowest observed value) and 1 (highest observed value). Because we pooled data from several ESS waves and, hence, points in time, we corrected for within-wave autocorrelation by using cluster-robust standard errors. For effect-size coefficients, we report unstandardized regression coefficients from ordinary least squares regressions; given the coding of the variables, these coefficients can be interpreted as indicating the change in percentage points of the full dependent-measure scale when the independent measure changes from its lowest to its highest value. In econometrics, this effect-size is viewed as the best effect-size measure for regression analysis (Achen, 1982, pp. 76–77). Table S2 in Supplemental Methods and Results summarizes the models whose results are discussed in the next section. In each model, we excluded observations missing values on one or more of the variables included in the model. We report two-tailed *p* values throughout the article.

Results

Does birth weight influence social trust in adulthood? Our results indicate that the answer is yes. First, controlling for respondents' gender and birth year, and the socioeconomic status of the family head, we found a significant and positive effect of respondents' birth weight on social trust; higher birth weight predicted higher levels of social trust in adulthood ($b = 0.07$, $p = .008$, $n = 1,554$; in a reduced model controlling only for gender and birth year, the effect was also significant, $b = 0.09$, $p = .005$, $n = 1,664$). Second, utilizing the sibling design, we estimated whether a parallel effect could be obtained by replacing the birth weight of each respondent with the mean birth weight of all the respondent's siblings in the registry or the birth weight of the respondent's closest younger sibling in the registry. We found no effect of either measure of sibling birth weight on social trust of the respondents (mean sibling birth weight: $b = 0.006$, $p = .695$, $n = 1,214$; birth weight of closest younger sibling: $b = -0.03$, $p = .11$, $n = 432$). These results strongly suggest that the results obtained in the first test were not due to omitted-variable bias related to genetic or environmental variables shared by siblings.

Third, we estimated the effect of the respondent's own birth weight on social trust controlling for sibling birth weight. The effect of the respondent's birth weight continued to be significant under this tighter control; in fact, it increased in size when confounds related to sibling birth weight were taken into account (model including mean sibling birth weight: $b = 0.07$, $p = .006$, $n = 1,214$; model including birth weight of the closest younger sibling: $b = 0.17$, $p = .031$, $n = 429$). We also found that the effect of the respondent's birth weight on social trust was robust when age and gender differences between siblings were taken into account (model including birth weight of the closest younger sibling: $b = 0.22$, $p = .017$, $n = 429$; see Supplemental Methods and Analyses).

In summary, combining a sibling design with high-quality, non-self-reported, nonretrospective measures allowed us to demonstrate an effect of birth weight on adult levels of social trust with substantial internal validity and measurement validity.

Study 2: Assessing Developmental Pathways: Birth Weight and Life-History Strategy

The aim of Study 2 was to investigate the developmental pathways between birth weight and social trust. We have argued that social trust forms part of an individual's more general life-history strategy. Accordingly, individual differences in trust should covary with a larger cluster of traits related to life-history trade-offs, such as sexual maturation and the motivation to delay gratification. Specifically, we predicted that low-trust individuals pursue a faster life-history strategy compared with high-trust individuals.

If life-history strategy is the developmental pathway from birth weight to social trust, a latent index of life-history traits should constitute a crucial statistical mediator between birth weight and trust. In contrast, previous research has primarily focused on how low birth weight gives rise to developmental deficits and impaired cognitive ability (e.g., Hack, Klein, & Taylor, 1995; Richards, Hardy, Kuh, & Wadsworth, 2002; Vohr et al., 2000). Accordingly, we directly compared the role of cognitive ability and life-history traits in the association between birth weight and social trust.

Method

We utilized a panel sample (Sample 2) of children and their mothers to investigate the pathway between birth weight and social trust. We tested whether birth weight was associated with a set of psychological differences related to later life history, such as motivation to delay gratification

and sexual maturation, and whether the latent trait underlying these differences served as the primary pathway between birth weight and social trust in later life.

We relied on data from the Danish Longitudinal Survey of Children (DALSC), which is a cohort study of 6,011 children. Parents of newborns were surveyed for the first time in 1996, when their children were 4 to 5 months old. Since then, the parents and children were surveyed when the children were ages 7, 11, and 15. Our analyses are based on between 3,300 and 4,097 children with complete data on relevant measures (the sample size varies because in a given analysis, we excluded all children with incomplete data on one or more of the included measures). Details on the sample's characteristics and the measures used are available in Supplemental Methods and Analyses (see Ottosen, 2011, for details on sampling decisions).

Birth-weight information was reported by mothers in the first wave of the DALSC ($M = 3,508$ g, $SD = 603$ g). Our primary dependent variable was social trust; when the children were age 15, they responded to the same social trust measure as used in Study 1. Answers were given on an 11-point scale and later recoded to a scale from 0 to 1 ($M = .63$, $SD = .19$).

The key life-history traits in our analysis were motivation to delay gratification and sexual maturity. To assess the motivation to delay gratification, we utilized a measure of the child's level of externalizing problems, as observed and reported by the mother at ages 7, 11, and 15. Externalizing problems are problem behaviors, often referred to as "acting out," that begin in childhood and originate in a lack of impulse control; examples include lying, hitting, and hyperactivity (Goodman, Lamping, & Ploubidis, 2010). Although these behaviors only indirectly tap the motivation to delay gratification, they have frequently been found to correlate with direct measures of a lack of motivation to delay gratification and are often viewed as a behavioral manifestation of this lack of motivation (e.g., Krueger, Caspi, Moffitt, White, & Stouthamer-

Loeber, 1996; Rapport, Tucker, DuPaul, Merlo, & Stoner, 1986; Wulfert, Block, Santa Ana, Rodriguez, & Colsman, 2002). Krueger et al. (1996), for example, concluded that “poor delay of gratification may be one of a select number of specific risk factors for externalizing disorder” (p. 107). Our measure of sexual maturity was whether the child had engaged in sexual intercourse by age 15.

In the analysis, we were able to include a large range of variables from the DALSC to control for potential key confounds caused by the child’s gender, the mother’s socioeconomic status, and the child’s general health status. These controls were the child’s gender, the mother’s education when the child was born, the mother’s income when the child was born, the mother’s smoking habits when the child was 4 to 5 months old, the child’s birth order as measured by the number of older siblings, the length of the mother’s hospitalization when the child was born, and the mother’s assessment of the child’s health at age 4 to 5 months (for details, see Supplemental Methods and Analyses). Controlling for these potential confounds increased internal validity. Some analyses also included the intelligence of the child at age 15 as assessed by Raven’s Progressive Matrices (Munk & Olsen, 2009, p. 4) in order to test the hypothesis that the effect of birth weight on social trust is less a matter of cognitive impairments than of life-history strategy. We used structural equation modeling to model a latent life-history-strategy trait and test for indirect effects of birth weight on trust through this latent trait. We report standardized coefficients as the measure of effect size.

Results

We first tested whether the effect of birth weight on social trust was replicated in this sample. Indeed, when we controlled for the range of potential confounds, we found that children with

higher birth weight expressed higher levels of social trust at age 15 ($\beta = 0.03, p = .048, n = 3,939$; in a reduced model controlling only for gender, the effect was also significant, $\beta = 0.04, p = .017, n = 4,097$).

Next, we specified a structural equation model with a latent trait influencing the range of life-history indicators—sexual activity at age 15; externalizing problems at ages 7, 11, and 15; and social trust at age 15. We specified an effect of birth weight on this latent trait. Furthermore, to evaluate the role of life-history strategy in the association between birth weight and social trust, we specified a direct effect of birth weight on observed social trust so that we could estimate whether the effect of birth weight on observed trust was fully accounted for when the latent life-history-strategy trait was included in the model. To compare the effects of life-history strategy and cognitive ability, we also included intelligence measured at age 15, specifying effects from birth weight to intelligence and from intelligence to social trust. All observed paths were controlled for the full range of control variables described in the Method section.

The path model, illustrated in Figure 1, showed a satisfactory fit with the data (root-mean-square error of approximation = 0.050, $n = 3,300$). Results were consistent with a life-history account. The latent life-history-strategy trait was significantly linked to both birth weight ($\beta = 0.05, p = .016$)³ and social trust at age 15 ($\beta = 0.12, p < .001$). The analysis confirmed that the indirect path between birth weight and social trust was statistically significant ($\beta = 0.01, p = .025$). The fact that these effects were observed in a model controlling for intelligence suggests that social trust forms part of a cluster of life-history traits that is influenced by birth weight independently of any effects of birth weight on cognitive impairments. In the model, we also observed an independent significant effect of intelligence on social trust ($\beta = 0.05, p = .009$; this effect is consistent with the role of cognitive ability in cooperation; see Dunbar & Shultz, 2007). In this

sample, however, intelligence was only marginally significantly related to birth weight when potential confounds (especially the mother's smoking habits) were taken into account ($\beta = 0.03$, $p = .08$; cf., e.g., Matte, Bresnahan, Begg, & Susser, 2001). The complete, indirect statistical path from birth weight to intelligence to social trust was insignificant ($\beta = 0.001$, $p = .15$), which suggests that a primary pathway between birth weight and social trust is established by a calibration of life-history strategy. Consistent with this idea, the path model showed that once this pathway was taken into account, birth weight no longer had a significant effect on social trust at age 15; that is, the direct effect of birth weight on social trust was not significant ($\beta = 0.03$, $p = .13$). These conclusions were reinforced by an analysis of robustness (reported in Supplemental Methods and Analyses).

Fig. 1. Results from Study 2: path model of the influence of birth weight on social trust , via life-history strategy and intelligence ($n = 3,300$). The coefficients were estimated using structural equation modeling, with all paths estimated simultaneously; p values are two-tailed. The model included the full range of control variables listed in the Method section. Boxes indicate observed variables, the circle indicates a latent trait, and numbers after @ are the year in which the variable was assessed.

Study 3: Assessing Effects of Stress in the Current Environment

Studies of life-history strategies suggest that childhood experiences modulate adult behavior more strongly when adult environments are more stressful (Griskevicius et al., 2013).

Conversely, adverse early life experiences might have less influence when adult environments are benign. In addition, studies have shown that birth weight calibrates the hypothalamic-pituitary-adrenal (HPA) axis, a neurological network tied to the regulation of stress; low-birth-weight individuals display increased stress reactivity (for an overview, see Gangestad, Caldwell Hooper, & Eaton, 2012). Furthermore, research on stress has directly linked stress-induced cortisol elevation to a downregulation of trust (Takahashi et al., 2005). Thus, the negative effects of low birth weight on trust may be particularly likely to emerge in currently stressful environments. We tested this possibility in Study 3.

Method

We expected to observe that the effects of low birth weight on social trust are particularly likely to be triggered in response to current stressful environments. To test this prediction, we relied on data from three samples, each providing a different operationalization of stress: (a) self-reported stress, (b) experimentally induced stress, or (c) biologically measured stress.

First, we again used the combination of data from the ESS and government registries for Sample 1. The ESS contains a measure of current life satisfaction that has previously been shown to assess—at least partly—current levels of distress and negative affect (Pavot & Diener, 1993).

The statistical setup and range of control variables in the analysis remained as described above with the addition of this measure and its interaction with the respondent's birth weight.

Second, to increase our leverage for testing a causal relationship, we designed an approximately nationally representative Web survey in which we experimentally manipulated current stress levels (Sample 3; see Supplemental Methods and Analyses for details on the sample's characteristics). Given the results for Sample 1, and taking missing data into account, we

determined that a total sample of 2,000 subjects would entail sufficient statistical power. We contracted with a Danish survey agency to collect the data on our behalf. Because we expected respondents to be unprepared for a question on their birth weight, the survey asked them to place their birth weight within predefined intervals of around 1,000 g.⁴ This information was provided by 1,503 respondents (75% of the total number of respondents; mode = 2,501–3,500 g). Some of these respondents failed to provide information regarding other measures, and we report results for a final sample of 648 respondents.

After providing birth-weight information, the respondents were randomly assigned to an experimental treatment designed to activate or deactivate stress (based on Navarrete, Kurzban, Fessler, & Kirkpatrick, 2004). Stress was activated by having respondents read a short vignette about a burglary of their home and describe their physical state in that situation; thus, respondents simulated physiological reactions to threats to property and safety. The control group read a short vignette about watching their favorite television program and described their physical state in that situation (see Supplemental Methods and Analyses for the full description of the vignettes). After describing their reactions, respondents reported their level of social trust. Thus, the procedure allowed us to test for a causal effect of stress on the link between birth weight and trust. To measure trust, we used the same question as for Sample 1. Following the advice of Uslaner (2009), however, we recorded answers using fewer categories (a 4-point scale) than the 11-point scale used in Studies 1 and 2 (after responses were recoded on a scale from 0 to 1, $M = .70$, $SD = .27$; higher values indicate greater trust). Finally, we also obtained data on the key control variables used in Study 1: gender, age, mother's education, and financial situation in early childhood.

The experimental online treatment used with Sample 3 did not allow direct biological measurements of stress. Therefore, as a third test, we analyzed data from an exploratory laboratory study that was completed by 32 university students (Sample 4; see Supplemental Methods and Analyses for details on the sample's characteristics). Chronologically, this was the first study on birth weight that we conducted; we simply obtained data from as many subjects as were willing to participate and provide measures of stress in the final month of the semester. Given the very low power of this sample in light of the effect sizes in Studies 1 and 2, any finding should be taken as suggestive. When signing up for the study, participants in Sample 4 were asked to contact their parents and obtain their exact birth weight prior to coming to the lab ($M = 3,547$ g, $SD = 537$ g).

To measure current stress, we relied on a fully implicit and physiological measure: hormone levels. The standard hormonal measure of current stress levels is the cortisol awakening response, that is, the rate of increase in cortisol levels in the first half-hour after waking in the morning. Greater stress has been shown to be highly associated with greater increases in cortisol levels upon awakening. This measure is superior to other cortisol measures because it controls for the large diurnal shifts in cortisol and is based on a comparison with an individual baseline (cortisol level in the minute after awakening; Fries, Dettenborn, & Kirschbaum, 2009; Wust et al., 2000). All participants were provided with two Sali-Tube test kits (manufactured by DRG® in Germany) for cortisol measurement, along with written and verbal instructions. They were instructed to provide two saliva samples the next morning: one immediately after awakening and another 30 min later. The samples were then returned to us and analyzed for cortisol levels at a large Danish hospital; the increase in cortisol from the first to the second sample was computed. To measure social trust, we used the same item and 4-point response format as in the online

survey (after responses were recoded on a scale from 0 to 1, $M = .79$, $SD = .22$; higher values indicate greater trust).⁵ Finally, we collected data on the same control variables used in the analyses of Samples 1 and 3.

To test how current stress modulates the effect of birth weight on social trust, we used ordinary least squares regression models that included a term for the interaction between birth weight and stress. We report F tests of these terms, with associated two-tailed p values. Following the recommended practice (Franzese & Kam, 2009), we used robust standard errors for the interaction models. (See Supplemental Methods and Analyses, Tables S5 and S6, for ordered probit coefficients for Samples 3 and 4, as well as additional details on the measures for these samples.)

Results

Across all three operationalizations of stress—self-reported stress, experimentally induced stress, and directly measured biological stress—the empirical findings provided tentative support for our prediction that the effects of low birth weight on trust are particularly likely to be triggered under stressful conditions.

Including self-reported stress (measured as life satisfaction) in the analysis of Sample 1 revealed a marginally significant two-way interaction between birth weight and self-reported stress, $F(1, 4) = 5.03$, $p = .088$ ($n = 1,548$). Figure 2a depicts the predicted marginal effects of stress on social trust as a function of birth weight in this sample. This graph shows that reactions to self-reported stress—as assessed by respondents’ current dissatisfaction with their life—were at least partly responsible for the main effect of birth weight on trust observed in Studies 1 and 2. When individuals with low birth weight experience stressful current conditions, a motivation to

withdraw socially seems to be triggered. In contrast, when individuals with high birth weight experience stressful current conditions, this does not reduce their high levels of social trust identified in Studies 1 and 2.

Fig. 2. Results from Study 3: predicted marginal effects of (a) self-reported stress (Sample 1, $n = 1,548$), (b) experimentally induced stress (Sample 3, $n = 648$), and (c) biological stress (Sample 4, $n = 32$) on social trust as a function of birth weight. The dashed lines represent 95% confidence intervals. The results shown are unstandardized regression coefficients from ordinary least squares regressions (see also Supplemental Methods and Analyses, including Tables S4–S6). Birth weight was rescaled to vary between 0 (minimum observed birth weight) and 1 (maximum observed birth weight) for each sample. All other variables were also rescaled to vary between 0 and 1.

This tentative conclusion was substantiated when we analyzed the effects of the experimental induction of stress in the nationally representative Sample 3. We found a significant two-way interaction between self-reported birth weight and experimental stress, $F(1, 640) = 4.23, p = .040$ ($n = 648$). Figure 2b shows the predicted marginal effects. These results replicate the pattern observed in the observational data from Sample 1: Among low-birth-weight individuals, lack of social trust seems especially likely to be triggered when current conditions are stressful.

Finally, the analysis of the effects of biological stress (Sample 4) revealed a marginally significant two-way interaction between cortisol awakening response and birth weight, $F(1, 24) = 3.35, p = .080$ ($n = 32$). Figure 2c shows the predicted marginal effects of stress on social trust as a function of birth weight. Thus, using a biological measure, we again found suggestive evidence that low-birth-weight individuals react with social distrust when stress is activated.

These final findings, however, should be treated with caution in light of the very low power of this sample. Adding to the need for caution is the fact that we did not replicate the interaction effect in this sample when we used an alternative three-item measure of social trust, although the effects were replicated when we used this alternative measure to analyze the data from the two larger samples (for discussion, see note 2 and Supplemental Methods and Results).

In sum, there is only tentative evidence that the social-cognitive effects of low birth weight can be alleviated in adulthood if environments are benign. In one sample, we found that current stress and birth weight had a significant interaction effect on social trust. In the other two samples, however, we found only a marginally significant interaction effect. Furthermore, in Sample 4, a small sample, the marginally significant interaction effect became insignificant when we turned to an alternative measurement of trust. To gain additional analytical leverage, we performed a meta-analysis combining the evidence from the three samples.⁶ For both our

standard measure of trust ($z = 2.81, p = .002$) and the alternative measure of trust ($z = 4.24, p < .001$), we found a significant interaction effect of stress and birth weight, such that low-birth-weight individuals had lower levels of social trust when they experienced more stress. Although the evidence remains tentative, it provides some promise that the social-cognitive effects of low birth weight can be alleviated to some extent by a lack of stressors in adult life.

Conclusion

Previous work on life-history strategies has shown that an individual's early childhood influences how he or she approaches family and friends in adult life. This article has provided evidence that extends this observation in two ways. First, as have a select number of recent studies, we have traced the correlates of life-history strategies into the intrauterine environment of an individual, as indexed by birth weight. Second, we have traced the correlates of birth weight to how an individual approaches not just friends and family but also strangers, as indexed by generalized social trust. Across samples of adults and children, we have provided evidence consistent with the hypothesis that low-birth-weight individuals have lower levels of social trust as adults compared with high-birth-weight individuals. Theoretically, we have suggested that this relationship is causal in nature. Although our analyses did not control for all possible confounds, we took a number of important steps toward increasing the internal validity of this claim; in particular, we controlled for the average birth weight of older siblings and childhood socioeconomic conditions.

Trusting other people often has beneficial consequences in modern society. Individuals who have higher social trust or are in higher-trust environments fare better in life and enjoy better health and higher incomes (Knack & Keefer, 1997; Poortinga, 2006). Similarly, research has shown

that high-birth-weight individuals fare better than low-birth-weight individuals when it comes to a number of outcomes, including health, education (Conley & Bennett, 2000), and earnings (Black, Devereux, & Salvanes, 2007). A potential driver of such differences in outcomes is cognitive impairments related to low birth weight. In linking birth weight to social trust as a component of life-history strategy, we have uncovered social trust as an alternative mediator of the adverse effects of birth weight. Our results support the argument that early, even intrauterine experiences give rise to differences in goals and motivations and not just differences in cognitive ability (Frankenhuis & de Weerth, 2013).

Theoretically, numerous factors can explain why a mechanism for calibrating social cognition on the basis of intrauterine experiences has evolved. Ancestrally, intrauterine experiences could forecast the future state or environment of the individual, and a regulation of social trust to match that state or environment could have been adaptive. Today, it is less clear that social withdrawal is adaptive for low-birth-weight individuals. Because health-care systems are better, and because environments in adulthood are presumably less correlated with environments in childhood, low-birth-weight individuals will not tend to face internal states or external environments as harsh as was ancestrally the case. In modern societies, the maladaptive effects of low birth weight on social behavior can even accelerate, as mistrust is essentially a self-fulfilling prophecy. Mistrust breeds mistrust, as evidenced by the literature on defection in public-goods games (Fehr & Gächter, 2000). Accordingly, low-birth-weight individuals might be less able to harvest cooperative surpluses than high-birth-weight individuals both because of their own mistrust and because of the reactions their mistrust and lack of impulse control breeds.

At the same time, it should be emphasized that a low birth weight is not the only or even the primary determinant of a lack of social trust in adulthood. The average effects we observed were

very small (i.e., effect sizes around 0.05). Also, we have provided tentative evidence that the adverse effects of low birth weight are alleviated if present environments are void of stressors. Given these observations, we are not making a claim about the magnitude of the effect of birth weight on social trust; rather, we are making a claim about the existence of this effect. In contrast to cross-disciplinary expectations, our analyses showed that birth weight has an effect on social trust over and beyond the effect of traditionally considered social and economic variables, such as the mother's education and income. Thus, the present study illustrates a larger theoretical point: Human social cognition cannot be analyzed separately from human biology. Social cognition, we suggest, is designed by evolution to respond adaptively to the biological contingencies of the individual.

Author Contributions

M. B. Petersen and L. Aarøe both contributed to developing the study concept, designing the studies, collecting the data, performing empirical tests, and drafting the manuscript. Both authors approved the final version of the manuscript for submission.

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Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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Supplemental Material

Additional supporting information can be found at
<http://pss.sagepub.com/content/by/supplemental-data>

Open Practices

The data for Sample 1 were obtained from the European Social Survey and government registries and cannot be made publicly available. The European Social Survey without the registry data can be accessed at <http://www.europeansocialsurvey.org/>. Data from the Danish Longitudinal Survey of Children (Sample 2) can be accessed at http://www.sfi.dk/about_the_research-11402.aspx. Data from our researcher survey and Samples 2, 3, and 4, and replication files for the analyses of those data, have been made publicly available via the Harvard Dataverse Network and can be accessed at <http://dx.doi.org/10.7910/DVN/GDIW9P>. The complete Open Practices Disclosure for this article can be found at <http://pss.sagepub.com/content/by/supplemental-data>.

Notes

1. This by-product could emerge through two different pathways. First, it could arise as a mere statistical effect of (a) the link between birth weight and life-history strategy and (b) trust being a subcomponent of a person's life-history strategy. Second, if lower birth weight makes individuals less reliable, they will likely be met with less trust from others and, correspondingly, downregulate their own trust in others.
2. Two other items in the ESS relate to social trust. In Supplemental Methods and Analyses, we provide a replication of the analysis in the main text using a scale created from all three items. Following the arguments raised by Uslaner (2002), we relied on the international-standard single-item measure of social trust ("most people can be trusted") as our primary measure, because previous research has shown that the two other items reflect personal experience with others. Extant findings also indicate that one of the other items ("Would you say that most of the time people try to be helpful or that they are mostly looking out for themselves?") is problematic because it does not scale with the other two items in some countries (Reeskens & Hooghe, 2008).
3. This link between birth weight and a trait related to sexual activity and impulsivity is consistent with findings of multiple studies (Frederick, 2012; Kajantie et al., 2008; Nettle et al., 2010). It should be noted, however, that there are mixed findings, especially when very and extremely low-birth-weight individuals are compared with individuals of average birth weight (Hack, 2006). Future research should address whether these mixed findings reflect the fact that birth-weight effects are different at the lowest end of the birth-weight spectrum, or whether they reflect the fact that the studies of very and extremely low-birth-weight individuals have low power because of small sample sizes due to the infrequency of such low birth weights.

4. This measure balanced concerns about measurement validity (i.e., obtaining a precise measure of birth weight) with concerns about external validity (i.e., not losing too many respondents because they lacked knowledge about their birth weight). The survey also contained an item that asked for respondents' exact birth weight and thus exclusively prioritized measurement validity. The findings reported in the main text were substantively replicated with this alternative measure (see Supplemental Methods and Analyses).
5. As were respondents in Sample 1, respondents in Samples 3 and 4 were given two additional items relating to social trust. See Supplemental Methods and Analyses for further discussion.
6. For this analysis, we used Rosenthal and Rosnow's (1991, pp. 503–504) formula for a weighted combination of three or more studies: $\sum(n_i * Z_i) / \sum n_j$, with i referring to a specific study, n referring to the sample size of the study and Z referring to the Z value of the effect in the study. This formula produces a combined Z value for the studies, weighting each study-specific Z value by the sample size of the study.

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