Empathy, estradiol and androgen levels in 9-year-old children

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Empathy, estradiol and androgen levels in 9-year-old children

Eider Pascual-Sagastizabal [a], Aitziber Azurmendi [a,*], José R. Sánchez-Martín [a], Francisco Braza [b], María R. Carreras [c], José M. Muñoz [c], Paloma Braza [c]

[a] Psychobiology Research Lab: Hormones and Child Behavior, CSIC-Associated Unit, Faculty of Psychology, University of the Basque Country, 20018 San Sebastian, Spain
[b] Doñana Biological Station, Spanish Council for Scientific Research (CSIC), 41092 Sevilla, Spain
[c] Child Development and Social Risk Unit, CSIC-Associated Unit, Faculty of Sciences of Education, University of Cadiz, 11519 Puerto Real, Spain

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ABSTRACT

The aim of this study was to analyze the possible relationship between circulating hormone levels (testosterone, androstenedione and estradiol) and empathy, as well as to identify any possible gender differences in this relationship. The subjects were 123 9-year-old Caucasian children (57 boys and 66 girls). Bryant's Empathy Index was used to measure empathy. Hormone levels were measured using an enzyme immunoassay technique in saliva samples. The Kruskal–Wallis test revealed the existence of interaction effects of estradiol-gender and testosterone-gender on empathy. Girls with low testosterone levels scored higher in Cognitive Empathy than girls with high testosterone levels. Boys with low estradiol levels scored higher in Affective Empathy than boys with high levels of this hormone. The results obtained open up new and interesting avenues of future research into the relationship between hormones and empathy in children.

1. Introduction

Over recent decades, research has highlighted the importance of empathy in individuals' prosocial disposition and its inhibitive function in relation to aggression. It is therefore vital to fully understand the nature of empathy, its development and its role in behavior.

Despite the numerous studies conducted with the aim of understanding this phenomenon (for a revision see Preston & de Waal, 2002), there has been, and indeed continues to be a lack of consensus regarding the exact nature of the concept. Historically, researchers have debated whether empathy is an affective construct or a cognitive one, or whether it is both at the same time. As a result of the debate surrounding these perspectives, over the last decade an increasingly clear tendency has emerged to treat empathy as a multidimensional construct which contains both cognitive and affective aspects. Eisenberg and Strayer (1987) defined empathy as an emotional response stemming from an understanding of the state or situation of others, claiming that it "is similar" to what the other person is feeling. The empathic response includes the ability to understand another person and put oneself in their shoes, based on what we can observe, the verbal information provided, the information accessible in our memory (a component which is closely related to theory of mind, and even to the ability to abstract the mental processes of others) and the affective reaction of sharing their emotional state, which may generate sadness, unease or anxiety.

A number of studies have found sex differences in empathy (for a revision see Rueckert, 2011). According to these results, women, in general, tend to empathize more than men. In other words, they have a greater tendency to identify the thoughts and emotions of others and respond in a more appropriate way. After comparing the results obtained through the application of different techniques to measure empathy, Eisenberg and Lennon (1983) concluded that women respond more empathically than men. A more recent study carried out by Mestre, Samper, Frías, and Tur (2009) also found that girls show more empathy in their responses than boys of the same age, and that these differences increase as subjects grow older.

Studies carried out with children have reached similar conclusions. Sex differences have been observed in the precursors to empathy from childhood onwards, indicating that girls prefer to look at social stimuli 24 h after birth (Connellan, Baron-Cohen, Wheelwright, & Ahluwalia, 2001). Girls also appear to engage in more comforting behaviors and adopt sad or understanding expressions when they observe another's discomfort or unease (Hoffman, 1977), and are better able to assess the feelings and intentions of characters in stories (Bosacki & Astington, 1999). In any case, it is important to bear in mind that other studies failed to find any sex differences in this respect. Thus, in a study carried

* Corresponding author. Address: Psychobiology Research Lab: Hormones and Child Behavior, CSIC-Associated Unit, Faculty of Psychology, University of the Basque Country, 20018 San Sebastián, Spain. Tel.: +34 943015713; fax: +34 943015670.

E-mail address: aitziber.azurmendi@ehu.es (A. Azurmendi).

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out by Roth-Hanania, Davidov, and Zahn-Waxler (2011) with babies aged between 8 and 16 months, no significant differences were found between boys and girls when the most rudimentary aspects of empathic capacity were measured.

Although some psychologists have suggested that empathy has a genetic basis (Hoffman, 1981; Rushton, Russell, & Wells, 1984), the role of biology in the development of empathy has, until recently, been the subject of little attention. Hoffman (1981) proposed that early displays of empathy indicated a biological root for its development. In this sense, and thanks to the discovery of mirror neurons, the majority of studies have focused on identifying the neural roots of empathy. For example, it has been discovered that the motor system of mirror neurons in empathic individuals is more active than in individuals who score lower in this aspect (Gazzola, Aziz-Zadeh, & Keysers, 2006).

Another series of studies have focused on the association between empathy or related aspects and hormone levels. Some studies have focused on the influence of pre and postnatal levels on the development of empathic capacity, while others have related circulating androgen levels to diverse aspects associated with empathy.

Prenatal exposure to atypical hormone environments results in alterations in human behavior, and sex differences have been observed in these alterations, including certain personality traits such as empathy. It is assumed that hormone alterations give rise to a specific type of brain development which underlies these behavioral results. Evidence of this has been found in women with Congenital Adrenal Hyperplasia, exposed to abnormally high levels of androgens (Hines, 2008). In specific terms, prenatal testosterone levels were found to significantly predict empathy levels at ages 4 and 8 (inverse relation both in the total sample and in boys) (Manson, 2008).

Autism is also related to high levels of prenatal androgens. Autistic people score lower than men in diverse tests which require empathic capacity or "intuitive psychology", and men score lower than women (Baron-Cohen, O'Riordan, Stone, Jones, & Plaisted, 1999; Baron-Cohen, Wheelwright, & Hill, 2001). From a biological perspective, it has been found that high fetal testosterone levels (measured in amniotic fluid) correlate with lower Child Empathizing Quotient scores (Chapman et al., 2006). These data support the ASC (Autistic Spectrum Conditions) theory, which proposes that high levels of fetal testosterone contribute to the differences in brain development that underlie the cognitive traits found in autism (Baron-Cohen, Lutchmaya, & Knickmeyer, 2004; Geschwind & Galaburda, 1985).

In addition to the studies which consider the influence of prenatal hormones, a number of authors have related circulating androgen levels to different cognitive abilities linked to empathy. Thus, Hermans, Putman, and van Honk (2006) found that in women aged between 19 and 31, the administration of a single dose of testosterone would attenuate empathic mimicry of emotional facial expressions. With regard to the relationship between androgen levels and the performance of diverse theory of mind tasks, Azurmendi et al. (2005) found a negative association between high androgen levels and affective labeling (the task consists of labeling the emotions represented in a series of drawings, which depict expressions of happiness, sadness, anger, and fear). In specific terms, these authors observed a negative relationship in boys between affective labeling and androstenedione, with this hormone being a predictor for this cognitive ability.

In another study carried out by van Honk et al. (2011) with 16 young women, the authors found that the administration of testosterone leads to significant impairment in the cognitive empathic ability to infer emotions, intentions, feelings and other mental states from the eye region of the face. Moreover, a proxy of subjects' fetal testosterone, the right-hand 2D:4D ratio, suggests that prenatal testosterone priming is crucial in this effect. In other words, fetal testosterone might critically mediate the activational effects of testosterone on human social behavior. Thus, their data convincingly show effects of testosterone administration on cognitive empathy, and these may depend on fetal testosterone priming.

Few studies have considered the relationship between circulating hormone levels and empathy in humans (Hermans et al., 2006; van Honk et al., 2011), and we are aware of no studies which have focused on this question in children. This study aimed to analyze the possible relationship between circulating hormone levels and empathy, focusing on sex differences in empathy in children, in order to identify any possible correlations with hormone levels.

2. Material and methods

2.1. Subjects

Subjects were 123 9-year-old Caucasian children (57 boys and 66 girls) from three public schools in Spain. The children's parents were provided with detailed information about the study and all gave their written consent. Although the tests used during this study were not invasive and were all carried out in the school itself, the project was pre-approved by the ethics committee at the institution to which the authors belong.

2.2. Procedures

The Empathy Index was administrated to all subjects between 09:00 h and 10:00 h. The test was administered by qualified, trained researchers in the classroom in each of the schools. Saliva samples, which were subsequently used for determining hormone levels, were taken on two different occasions (both at the same time, 09:00 h., with an interval of 6 weeks) during the administration of this test. In order to obtain a base line for each hormone in each subject the two values of each hormone were averaged, as they were correlated (estradiol: $r = 0.527$, $P = 0.000$; testosterone: $r = 0.571$, $P = 0.000$; androstenedione: $r = 0.704$, $P = 0.000$).

2.3. Empathy measure

To measure empathy, we used Bryant's Empathy Index for children and adolescents (Spanish version by del Barrio, Aluja, & García, 2004). This scale is the modified version of Mehrabian and Epstein's scale (1972), designed to measure trait (rather than state) empathy. The analysis of the internal consistency of the instrument carried out by Bryant (1982) found a mean Cronbach's alpha of 0.67, which increased in accordance with subjects' age. It consists of 22 items and, as recommended by the author for children in this age group, we scored the items dichotomously (1 or 0 for yes or no, true or false), with high scores reflecting high empathy (Bryant, 1982). Since Bryant's Index is a multidimensional scale, a factorial analysis needs to be performed in order to interpret the results. There are two studies which analyze and then replicate the factor structure of Bryant's Empathy Index in Spanish children (del Barrio et al., 2004; Lasa, Holgado, Carrasco, & del Barrio, 2008). In these studies, the authors found that the three-factor structure appears to be appropriate for children and adolescents and reinforces the validity of the cognitive and affective components of the scale, as well as that of the construct of empathy. This structure includes a cognitive factor (Understanding Feelings, consisting of 9 items) and two affective factors (Feelings of Sadness and Tearful Reaction, consisting of 6 and 7 items, respectively). The cognitive factor refers to situations in which the child arrives at an understanding of other children. As regards the affective factors, Feelings of Sadness is related to situations in which the child experiences an emotional state similar to that of the object, and Tearful Reaction is related to emotion contagion and sympathy (Lasa et al., 2008). These are the three factors used in our study. The Cronbach's alpha for these sub-scales was 0.60 for Understanding Feelings, 0.72 for Feelings of Sadness and 0.53 for Tearful Reaction.

2.4. Determination of salivary hormone levels

Saliva samples were taken by passive drool into a plastic cup. Samples were frozen and stored in the laboratory at −80 °C until analysis. On the day of the analysis, the samples were centrifuged at 3000 rpm for 15 min to remove mucins. Both samples for each subject were assayed in duplicate. The average of each duplicate test was used in the analyses. All samples were assayed using an enzyme immunoassay kit (Salimetrics, State Collage, USA). For testosterone, the average intra-assay coefficient of variation (CV) was 6.7% and the average inter-assay CV was 9.6%. For androstenedione, the intra and inter-assay CVs were 5.6% and 3.4% respectively. Finally, for estradiol, the intra and inter-assay CVs were 8.1% and 3.4%.

2.5. Statistical analysis

The results of the empathy scores and hormone levels showed a non-normal distribution. An attempt was made to normalize the data using different statistical techniques, but since it was not possible to adjust our data to the normal curve, we opted instead to use the non-parametric Kruskal–Wallis test, as we had 4 independent groups. Boys and girls were divided separately into two groups according to percentile distribution (Low: less than or equal to 0.50; High: higher than 0.50). For the analysis of the sex differences in hormones and empathy and for post hoc comparisons (when necessary), we used the Mann–Whitney test. The level of significance was set at $p < 0.05$.

3. Results

3.1. Sex differences in hormone measures and empathy

Our results failed to show any sex differences in empathy scores. In the case of hormones, sex differences were only found for androstenedione ($U = 683.00$; $z = -2.915$; $p = 0.002$) with girls having higher levels than boys.

3.2. Relationships between sex, empathy scores and hormone levels

In the case of Cognitive Empathy (Understanding Feelings), we found a statistically significant interaction for sex and testosterone levels $H(3) = 7.699$; $p = 0.05$. A post hoc analysis revealed that girls who had low levels of testosterone scored higher in Understanding Feelings than boys with low levels ($U = 156.5$; $z = -2.610$; $p = 0.004$; $r = -.38$) and girls with high levels ($U = 208.00$; $z = -1.870$; $p = 0.031$; $r = -.27$) of this hormone (see Fig. 1).

As regards Affective Empathy (Feelings of Sadness), the results revealed a statistically significant interaction for sex and estradiol levels $H(3) = 10.943$; $p = 0.012$. A post hoc analysis revealed that boys with low levels of estradiol scored higher in Feelings of Sadness than boys with high levels ($U = 237.00$; $z = -2.468$; $p = 0.007$; $r = -.33$), girls with high levels ($U = 322.00$; $z = -1.766$; $p = 0.039$; $r = -.23$) and girls with low levels ($U = 241.00$; $z = -2.990$; $p = 0.001$; $r = -.39$) of this hormone (see Fig. 2).

No differences were found for Tearful Reaction, sex and hormone levels.

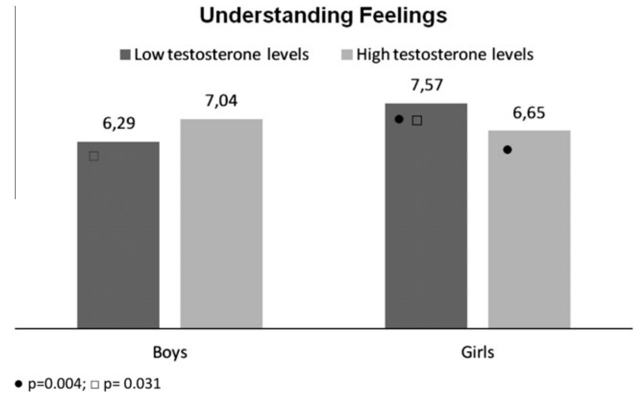

Fig. 1. Interaction between testosterone and gender on Understanding Feelings.

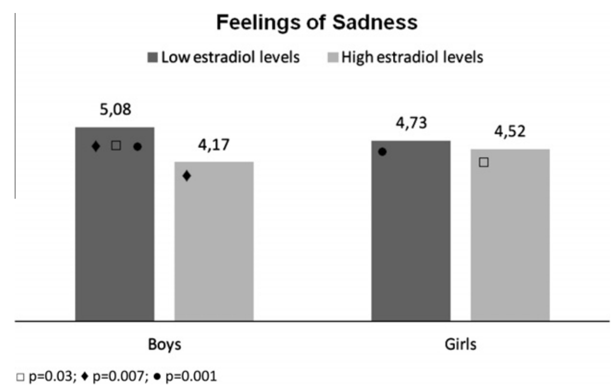

Fig. 2. Interaction between estradiol and gender on feelings of sadness.

4. Discussion

Few studies have focused on the relationship between hormone levels and empathy in children, and those that have done so have mainly studied the organizational influence of hormones (at a prenatal level) on subsequent empathic capacity. This study, however, aimed to analyze the possible relationships which may exist between empathy and circulating hormone levels (estradiol, testosterone and androstenedione). Given that many studies have found sex differences in empathic capacity (with girls outperforming boys from early infancy onwards), our aim was to study the possible hormonal correlates of these differences.

The most interesting result of our research was that, despite failing to find any sex differences in empathic capacity, estradiol and testosterone levels, the relationship between these variables was different for each sex. In specific terms, girls with low testosterone levels scored higher in Understanding Feelings (Cognitive Empathy) than girls with high testosterone levels. Also, girls with high testosterone levels scored similarly in Cognitive Empathy to boys with both high and low levels of this hormone. These results are consistent with those found by van Honk et al. (2011), where the administration of testosterone to young girls was observed to have a negative effect on their cognitive empathy.

Another interesting finding in our study is that boys with low levels of estradiol scored higher in Feelings of Sadness (Affective Empathy) than boys with high levels and girls with both high and low levels of this hormone. For their part, the Affective Empathy scores of boys with high levels of estradiol were not significantly different from those obtained by girls. These results may be interpreted in terms of sex differences in the brain and in behavior. The differentiation of the nervous system, and consequently behavior, is guided by the same steroids that are responsible for sexual differentiation between male and female bodies (Breedlove & Hampson, 2002). We know that, in the developing brain, androgens generate sex differences in neural structure and function. All the cells in the sexually dimorphic regions of the brain are rich in androgen receptors and their development is mainly affected by testosterone, during both early fetal life and subsequent periods (Baron-Cohen, Knickmeyer, & Belmonte, 2005). Estrogens also affect development at a cellular level and are believed to underlie the sexual differentiation of the neural circuits responsible for specific sex behaviors and neuroendocrine functions (Kelly, 1988; Pilgrim & Hutchison, 1994). During brain development, estrogens help organize the neural circuits that control a wide range of neuroendocrine, behavioral and cognitive functions (Arnold & Gorski, 1984). Alterations in the estrogenic environment of the central nervous system (CNS) during development may affect critical aspects of cellular differentiation, influencing the formation of synapses, the process of myelination, the expression of neurotransmitters and neuropeptides and the death and survival of individual cells. Thus, estrogens also seem to be crucial to the sexual differentiation of the structures and functions of the CNS (Beyer, 1999).

The effects of steroid hormones on the CNS can be classified as both organizational and activational. Organizational effects refer to the ability of steroids to sculpt the structure of the central nervous system during its development. Activational effects, on the other hand, refer to the ability of steroids to modify the activity of target cells in order to facilitate behavior in a specific social context (Sisk & Zehr, 2005).

Because of the early organizational effects of hormones, there may be important sex differences in sensitivity to sex steroids from very early in life. In fact, evidence exists that individuals differ not only in their levels of circulating hormones but also in their sensitivity to them (Cohen-Bendahan, van den Beek, & Berenbaum, 2005). Thus, a similar mechanism may underlie the results obtained in our study. Despite not finding sex differences in any of the variables studied, we did find a relationship between hormones and empathy that was different for each sex.

In the case of testosterone, girls with high levels scored similarly in Cognitive Empathy to boys with both high and low levels, while girls with low testosterone levels differed significantly from the other three groups, scoring higher in Cognitive Empathy. We know that high testosterone levels have a negative influence on Cognitive Empathy in girls (van Honk et al., 2011); in our study, we found that girls with low testosterone levels scored higher in Cognitive Empathy. van Honk et al. (2011) also found that the administration of testosterone had a negative influence on cognitive empathy in those girls with high prenatal testosterone levels measured using the 2D:4D ratio (organizational effects). It may be that girls have a higher threshold than boys for circulating testosterone to have a significant effect on behavior or its underlying psychological mechanisms. Boys, having more androgen receptors due to their organizational influence, may be affected by lower testosterone levels, or in other words, may have a greater physiological sensitivity to testosterone.

We believe that a similar mechanism underlies the results found in boys for estradiol. It was boys with lower levels of estradiol who scored highest in Affective Empathy. In addition to alluding to the sensitivity difference between the sexes outlined in the previous paragraph, this result could also be explained by taking into consideration the potential masculinizing effects of estrogen on the male brain, more than on the female one. A paradoxical observation in relation to the irreversible effects produced by testosterone on the CNS is that, at least in female rats, the androgenic molecule must be intraneuronally transformed into estradiol. Thus, one of the hormones which determines the masculine differentiation of the brain is, in fact, the one considered to be quintessentially female. Females are protected from the masculinizing effects of estradiol thanks to alpha fetoprotein, which deactivates circulating estradiol by bonding to it. The importance of estradiol in the masculinization of the brain has been demonstrated by different experimental approaches (McCarthy, 2008), and despite the fact that these effects have yet to be established in humans, we believe that similar action mechanisms may exist in the male and female brains of our species.

As regards the fact that no sex differences were found in empathic capacity, it is worth mentioning that there are as many studies that have established sex differences, as those that have not (Rueckert, 2011). In their review of sex differences in empathy, Eisenberg and Lennon (1983) concluded that there was no evidence of differences in this regard between men and women. In the majority of the studies reviewed, no significant differences were found in subjects' responses in accordance with sex, and in the studies that did find said differences, the results were evenly split in favor of both men and women. The final assessment made by the authors after having compared the results from the application of different techniques for evaluating empathy is that the data on sex differences in empathy are inconsistent, and that said inconsistency depends on the method used to measure this capacity; in other words, methodological difficulties were observed in the assessment of psychological states and there is a lack of differentiation between diverse emotional responses. Although over recent years much progress has been made in the development of techniques for measuring empathy, we believe that it is still necessary to further adapt and refine both methods and theory in this field.

As mentioned earlier, empathy is not a unidimensional construct, and to date, there is insufficient scientific evidence to confirm whether the two components of empathy (cognitive and emotional) are parts which interact within a single system, or whether they are independent of each other, although it has recently been shown that the neuronal circuits that regulate them are different (Shamay-Tsoory, Aharon-Peretz, & Perry, 2008). Consequently, the influence of hormones may also be different. It is likely that early organizational effects are manifested through a specific sensitivity of each sex to specific hormones (or to certain levels of hormones). Also, and as Archer (2006) points out, it is likely that hormones are associated with the life histories of each specific subject (for example, certain androgen levels may be associated with certain ability levels).

Although the influence of sex hormones on cognition and behavior is more evident both in those stages during which their organizational effects are more acute and in those in which their circulating levels differ more widely between the two sexes, the results obtained in our study support the idea that, even in stages in which hormone levels are low and hardly present any sex differences, a relationship can be observed between hormones and empathy. The results obtained open up new and interesting avenues of future research into the relationship between hormones and empathy in children.

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