Hormones and Behavior at Early Adolescence: A Theoretical Overview

Christy M. Buchanan

Stanford University

Jacquelynne S. Eccles

University of Colorado

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**For a more detailed exposition of the ideas in this text, please see Buchanan, C.M., Eccles, J.S., & Becker, J.B. (1992). Are adolescents victims of raging hormones: Evidence for activational effects of hormones on moods and behavior at adolescence. Psychological Bulletin, 111, 62-107.

Hormones and Behavior at Early Adolescence: A Theoretical Overview

In the early and mid-1980's there was a surge of interest in questions of hormones and behavior at adolescence, and a handful of studies were funded that produced a critical mass of data about possible associations between these domains. The data that emerged were provocative in terms of providing substantive information about what might be going on between the biological and psychosocial systems, but also quickly pointed to a number of methodological and conceptual complexities. In this talk, we first suggest several potential conceptualizations of hormone effects. We offer evidence for each conceptualization given the existing empirical data from hormone-behavior studies at adolescence, as well as from data on hormones and behavior in nonhuman animals and adults. We then point out future research needs that stem from these alternative conceptualizations, and from substantive gaps in the available literature.

Possible types of hormone-behavior associations.

The possible types of hormone-behavior associations I will outline are not incompatible with one another; in fact, there clearly are elements that overlap across categories. But each of these conceptualization provides a slightly different way of thinking about how hormonal effects may occur, with implications for measurement and interpretation of results.

1. Activation effects represent the most traditional conceptualization of concurrent hormone activity. These effects refer to the association of rising (or falling) tonic or average concentrations of hormones with heightened or reduced levels of moods or behaviors. There are several empirical examples of this type of hormone activity. In nonhuman animals, estrogen is associated with lowered thresholds of excitation(i.e., greater sensitivity to or tendency toward excitation), whereas progesterone is associated with higher thresholds. There is evidence among human adults that estrogen stimulates more positive moods, and lack of estrogen is associated with depression and negative affect, mainly in women. The common, albeit simplistic, association of testosterone and aggression would also fall into this category.

Examples of potential "activation effects" found among adolescents by various research groups include: higher estrogen related to more positive moods over the course of 1 month in early-adolescent girls (Eccles et al., 1988); higher androstenedione levels related to lower energy levels among early-adolescent boys (Nottelmann et al., 1985); higher testosterone related to lower tolerance for frustration among adolescent boys (Olweus, 1986); higher LH associated with more anger/impatience among boys (Eccles et al., 1988); high adrenal hormones related to higher anxiety in boys (Susman et al., 1991); and low sex steroids and high adrenal androgens associated with less positive self-image among boys (Nottelmann, Susman, Blue et al., 1987; Nottelmann et al., 1990). In what we are calling activation effects, levels of a hormone are correlated, either negatively or positively, with levels of a mood or behavior of interest. In many cases, this correspondence has been thought to transcend species or developmental stage (e.g., estrogen and happiness, testosterone and aggression).

It is important to keep in mind that when hormones rise or fall to extreme levels, effects may be different than when hormones rise or fall within a more moderate range. For example, one study of post-menopausal women indicated that very low levels of estrogen were associated with depression, moderate levels with well-being, but very high levels with anxiety (deLignieres & Vincens, 1982).

2. Adjustment effects. We use the term adjustment effects to refer to hormonal influences on behavior that result from deviations in the level of hormones to which an individual is accustomed. They are essentially activational effects that differ depending on developmental stage, or previous exposure. For example, one might see more extreme or different effects of hormones on behavior during pre- and early adolescence than in middle or later adolescence, or in adulthood, because by the middle and later adolescent years,

teenagers have adapted to heightened concentrations of hormones. One example of an empirical finding indicating that hormonal effects vary depending on age or stage of development comes from the laboratory of Brooks-Gunn. Although estrogen is typically associated with higher general activation and greater feelings of well-being in animals and adult humans, Brooks-Gunn and her colleagues find that estrogen predicts higher levels of depression for girls in the early stages of puberty, when estrogen is rising most rapidly (Brooks-Gunn & Warren, 1989). Brooks-Gunn & Warren (1989) also found a relation between higher estrogen and lower impulse control for girls in early but not later adolescence.

Susman, Nottelmann, and their colleagues have documented a number of instances in which high concentrations of certain hormones FOR ONE'S AGE (i.e., androstenedione or FSH) are associated with more negative mood states (e.g, Nottelmann, Susman, Blue, et al., 1987; Nottelmann, Susman, Inoff-Germain et al., 1987; Susman et al., 1985). These results are consistent with a model whereby deviations from what has been typical for an individual at his or her stage of development are more important with regard to moods or behavior than are absolute hormone levels. In addition, the many findings of the Susman and Nottelmann group linking adrenal androgens--but not testosterone--to negative affective and behavioral outcomes may indicate that it is primarily early hormonal changes that predict negative outcomes. (On the other hand, of course, this particular finding may simply indicate that adrenal androgens are more important in the early adolescent years while testosterone assumes greater importance later on.)

(3) Irregularity effects. The third possible kind of effect we have labelled an "irregularity effect". In early adolescence, gonadotropins and sex steroids not only increase in concentration, but increase in variability and instability. Episodic activity (or periodic pulses of hormones) and cyclic patterns of hormone release begin, and these patterns can be quite irregular during the initial phases of hormonal change. Fluctuation of hormones, especially if those fluctuations are irregular, might lead to instability of nervous functioning, with potential implications for moods and behavior. Most of the empirical support for this particular conceptualization comes from studies of adult women. Irregular or atypical patterns of pulsatile or cyclical activity in adult women have been linked to negative mood and behavioral symptoms. For example, Dennerstein et al. (1984) found that hormonal characteristics of the menstrual cycle differed between women experiencing premenstrual syndrome, or PMS, and women not experiencing PMS. Women who had PMS showed several "irregularities," including lower peaks of estradiol before ovulation, and either lower or higher estradiol during the luteal phase. Backstrom et al. (1976) also found hormonal irregularities, such as an abnormal luteal rise in FSH, in a group of women with PMS. In addition, Coppen & Kessel (1963) found that neuroticism in women was linked to irregularity of the menstrual cycle.

In terms of adolescent data, at the University of Michigan we have been able to look at the relation between hormone variability and moods/behavior because we collected both hormone and mood/behavioral data 3 days a week for 4 weeks. So far have found limited but occasional links between variability and moods (e.g., higher variability of E2 related to more moodiness when using self-reported moodiness).

4. Complex interactions. Hormonal effects, whether conceptualized as activation, adjustment or irregularity effects, are likely to interact with other biological and nonbiological factors such as (a) an individual's sensitivity to the hormone; (b) individual predisposition to the behavior of interest; or (c) contextual factors. There is actually quite a bit of evidence for these types of interactions in the limited empirical data base on hormones and behavior at adolescence. Evidence for these interactions is also available based on information about age changes in behaviors that might be correlated with hormonal change over the adolescent years.

First, differences in individual sensitivity are demonstrated by Udry & Talbert's (1988) finding that smaller differences in testosterone were associated with greater

differences in personality dimensions (of extraversion, aggressive styles,etc.) for girls than for boys.

Second, the importance of individual predisposition is demonstrated by several studies documenting that depressive problems and aggression are especially likely to increase at adolescence for children already experiencing these problems (Achenbach & Edelbrock, 1981; Bettes & Walker, 1986; Rutter et al., 1976). This suggests that if pubertal hormone changes do influence depression or aggression, the effects may be most pronounced for adolescents already prone to psychological or behavioral problems or in environments likely to elicit a depressive or aggressive reaction. Some evidence for stronger effects of hormones among people already prone to trouble comes from studies of teenage boys and adult men indicating that testosterone is linked to aggression in deviant populations (e.g, delinquent boys and criminal men) but not in populations of normal males (Mattsson et al., 1980; Rubin et al., 1980). Two longitudinal studies of hormones and behavior at adolescence have explicitly tested interactions between hormones and prior depression/ aggression in predicting later behavior. In one study significant interactions did not emerge (Paikoff et al., 1991) and in the other there were several interactions that approached but did not reach statistical significance (Susman et al., 1991). In addition, in this latter study, the direction of the interaction was different for boys and girls. Although these two early attempts to find evidence of stronger hormonal effects for individuals already exhibiting certain psychological or behavioral problems do not provide support for the hypothesis, we believe that such effects are theoretically feasible and worth further exploration.

Finally, evidence that the effects of hormones depend on contextual factors comes from Olweus et al. (1980; 1988) who found that boys with higher levels of testosterone were more likely to be aggressive UNDER CONDITIONS OF THREAT OR UNFAIR TREATMENT. When no provoking situation occurred, testosterone levels did not predict aggression. Given that testosterone was linked to a lower tolerance for frustration, one can easily see how two boys with equally high testosterone concentrations, and thus equally low thresholds for frustration, could exhibit very different levels of aggression depending on the environment. One boy might never exhibit aggression because he is never or hardly ever provoked---his tolerance for frustration, although low, is not exceeded. The other boy, meanwhile, might exhibit a great deal of aggression because he is provoked in some way, perhaps repeatedly, by his environment. His low threshold for frustration is repeatedly exceeded.

Another very interesting example of the different effects of hormones depending on context is Udry's (1988) finding that the generally strong relation between testosterone and sexual involvement among 12- to 16-year girls was reduced or eliminated by the girl's participation in sports or by the presence of a father in the home. These environmental variables likely reduced opportunities for sexual involvement, thus overriding any hormonal effects on sexual behavior.

Finally, the common finding of sex differences in the existence of hormonal effects or the type of hormonal effects may also indicate the role of personality predispositions or social context in moderating hormone activity.

Having described some potential conceptualizations of hormone activity, I will spend the remainder of the time identifying potentially fruitful avenues for further exploration of hormone-behavior relations, based on substantive findings and gaps in findings in the literature already available as well as these possible alternative conceptualizations. The conceptualizations have particularly strong implications for methodological issues in future work, but I want to integrate these conceptualizations with a discussion of more substantive needs as well.

(1) Substantively, the field of research on hormones and behavior at adolescence could benefit by focussing on moods, affect, and very simple behaviors in addition to the more complex behaviors that have often been studied. The types of moods or simple

behaviors we are referring to are, for example, mood swings (or mood lability), mood intensity, sadness or depressed affect, energy levels, irritability, and restlessness. With the exception of depressed affect, these types of moods, or simple behaviors that might reflect moods, have received very little attention either in studies of behavioral change at adolescence or in studies of hormones and behavior. Not only are these characteristics components of some of the most common stereotypes assigned to adolescents, they may be more proximally related to hormones than the more complex behaviors usually studied (e.g., aggression, family conflict, or self-esteem). In addition, these characteristics of affect and mood may mediate relations between hormones and more complex aspects of behavior or personality. In a test of this type of mediational model Dan Olweus and his colleagues found that boys with higher testosterone levels had a lower tolerance for frustration, which in turn led to an increased tendency to respond aggressively in situations that were provoking, or frustrating. Much of the research on hormones and behavior has concentrated only or primarily on the more complex aspects of behavior and personality, and direct links between hormones and these behaviors may be very difficult if not impossible to detect given the multiple influences on such behaviors.

(2) Hormone-behavior research at adolescence could also benefit from a focus on the late childhood or very early adolescent years. Such a focus potentially provides several important advantages. First, because hormonal changes precede morphological changes, a focus on late childhood and very early adolescence would allow, at least to some degree, an examination of hormonal and behavioral changes apart from outward morphological changes that are associated with hormonal changes. Second, hormonal changes can be examined apart form the many salient social changes that occur with entry into junior high school and high school. Third, as we have suggested, influences of hormones when they first begin to rise and cycle may be different from hormonal influences later on when concentrations have stabilized. At the very least, a late childhood/very early adolescent group should be studied IN ADDITION to older adolescents, in order to be able to examine differences in hormone effects depending on age or environmental contexts. What we want to emphasize here is the importance of thinking carefully about developmental stages WITHIN adolescence in terms of conducting or evaluating hormone-behavior research.

Of course, one consequence of a focus on the earlier time period is the need to examine those hormones that show some of the earliest changes: the adrenal androgens and the gonadotropins. Although we know of no brain receptors for the gonadotropins, and therefore no direct mechanism of effect, early changes in the gonadotropins may signal some of the very first changes in sex steroids (testosterone and estrogen) -- changes that are extremely small and difficult to detect, but that may be very important emotionally and behaviorally nonetheless.

(3) Obtaining repeated measures of hormonal and behavioral data from individual subjects would provide several advantages. First, we believe there is a strong need to study within-subject hormonal effects. Potential differences in individual sensitivity to hormones mean that, even within subgroups (e.g., girls, or younger adolescents) certain individuals will be more strongly influenced by hormones than others. Tracking hormonal and affective or behavioral activity over time in individuals would allow one to detect hormone-behavior associations that would be lost in a between-group analysis, because of differences in strength or direction between individuals. In our laboratory at the University of Michigan, we have compared a within-subject and a between-subject approach using our sample of early adolescents. We are finding that within-subject hormone-behavior relations are often different from between-subject findings. We need to examine these data further to see if we can identify personality or contextual factors that can account for some of these individual differences--and of course the findings need to be replicated--but the existence of the individual differences certainly raises questions about the field's reliance on a between-subjects approach.

Second, repeated sampling of hormones would allow examination of questions of variability and regularity in hormone activity. We have discussed the potential importance

of hormone variability. Repeated sampling of moods and behavior would allow a look at variability and regularity of psychological and emotional states. The few data available on moodiness at adolescence already indicate the potential importance of this kind of measurement for moods. Studies that directly asked adolescents or their parents about "Moodiness" (e.g., do your moods change frequently, quickly) have not documented as many relations with pubertal status or hormone activity as have those that measured moodiness as variability of specific moods over the course of time. In another example, hormones were found to be related to variability (but not absolute levels) of energy and restlessness in early-adolescent girls (Buchanan, 1991).

A third advantage of multiple measures is the potential to examine different time lags in the study of hormone-behavior effects. The critical issue of how long it takes for hormones to influence behavior has not been adequately considered. Are hormonal effects immediate or delayed? If delayed, for how long? A day? A week? A month? In the majority of studies on adolescent hormones and behavior, behavioral and hormonal data have either been assessed concurrently or separated in time by approximately a month. Thus, short-term lags are not picked up, and what seem to be concurrent effects may be invalid if the behaviors actually reflect hormones at some previous point in time. Much of the existing research base uses a "trait-like" approach, in which it is assumed that measures of hormones at one point in time are indicators of stable individual differences in average concentrations and that the key research question is the association of individual differences in hormone concentrations and individual differences in other personality-behavioral-affective traits. Although this may be a valid conceptualization of hormonal activity, what we know about the changing, unstable nature of hormones at adolescence suggests several interesting alternative possibilities, all of which require a more careful consideration of the appropriate time lag between hormonal assays and affective-behavioral measures. Until we know more about the appropriate time lags, multiple measures over time would provide the opportunity to examine alternative lags.

A fourth advantage of multiple measures over time is the possibility to test direction of effect. I have not yet mentioned what I'm sure many of you are thinking about and that is that moods, behaviors, and environmental circumstances certainly influence hormonal levels during adolescence as they do at other developmental periods. In fact, the primary explanation given by Nottelmann and Susman and their colleagues for their consistent finding regarding the association of negative affect and behavior with high adrenal androgens (primarily androstenedione) in combination with low sex steroids (primarily T) is that stress in the environment is provoking the hormonal patterns. One potential stress might be late pubertal development for boys, because it is among late-developing boys that this type of association between hormones and behavior was often seen. There is a strong case to be made for repeated-measures designs in order to be able to investigate causal orderings.

We have covered just a few of the conceptual and methodological considerations to be reckoned with in studies of hormones and behavior at adolescence, but we feel they are some of the most central given the current state of the field.

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