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The Hormonal Correlates of Implicit Motives

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Abstract

Implicit motives represent nonconsciously represented dispositions to seek specific classes of incentives and to avoid corresponding classes of disincentives. Growing evidence suggests that the implicit power motive is associated with basal levels and reactivity of the gonadal steroid hormones testosterone in men and estradiol in women. It is also associated with increased release of stress hormones (cortisol, norepinephrine) in response to dominance challenges and social defeat. The implicit affiliation motive is linked to the release of progesterone: increases in progesterone are followed by increases in affiliation motivation, and arousal of affiliation motivation is associated with concurrent or subsequent progesterone increases. There is limited evidence for a role of vasopressin in achievement motivation. These findings point to a key role of the hypothalamus for implicit motives, a role that is consistent with the existence of function-specific nuclei within this brain area.

Introduction

Since the late 1950s, a growing body of research documents a physiological basis for implicit motivational needs in humans (McClelland, 1987; Schultheiss, 2008). This research also provides evidence for specific associations between implicit motives and hormonal parameters. In the present paper, I will summarize the current state of knowledge regarding the hormonal correlates of implicit motives and also discuss the significance of the motive-hormone link for understanding the biological roots of implicit motives.

Implicit motives amplify affective responses to specific classes of incentives and disincentives (Atkinson, 1957; Schultheiss, 2008). They thereby influence which cues and behaviors associated with (dis)incentive contact are learned (selecting function), which stimuli in the environment and individual attends to (orienting function), and the intensity, frequency, and persistence of an individual's behavioral responses to incentive cues (energizing function; McClelland, 1987). Implicit motives are measured through content coding of imaginative stories individuals generate in response to pictures showing people in ambiguous social situations. This procedure is called the Picture Story Exercise (PSE) and represents a descendant of Morgan and Murray's (1935) Thematic Apperception Test (TAT). Unlike the TAT, however, PSE measures of implicit motives have been validated in experimental studies, by arousing a motivational need in one group of participants, but not in a control group, and condensing the story themes on which the two groups differed into content coding systems. These coding systems are then used to assess the strength of motivational needs in research participants tested under neutral conditions (Schultheiss & Pang, 2007; Winter, 1998a,b, Appendix). PSE motive measures thus satisfy the central criterion for a measure's validity, as proposed by Borsboom, Mellenbergh, and van Heerden (2004): that the purported measure of a construct varies with experimental manipulations of the construct itself. PSE motive measures have high inter-rater reliability and substantial retest reliability over extended periods of time (Schultheiss & Pang, 2007).

They also have considerable ipsative (or profile) stability across picture items from one testing session to the next (Schultheiss, Liening, & Schad, 2008). The criterion validity of PSE motive measures for a wide variety of behavioral and life outcomes is well established (see McClelland, 1987; and Schultheiss & Brunstein, 2010; for reviews) and supported by meta-analyses (Collins, Hanges, & Locke, 2004; Spangler, 1992).

One key property of PSE motive measures that has been observed from the very beginning (e.g., deCharms, Morrison, Reitman, & McClelland, 1955) and confirmed by meta-analysis (Spangler, 1992) is that they do not share substantial variance with self-report measures of motivation. This finding suggests that PSE motive measures tap into motivational dispositions that reside outside of the reach of valid introspection (hence the term *implicit*; see McClelland, Koestner, & Weinberger, 1989). Measures of implicit motives must be clearly distinguished conceptually and empirically from self-report (or explicit) motive measures not only because of this lack of statistical overlap, but also due to the different validation criteria used to derive them (see Schultheiss, in preparation) and the different types of outcomes they are associated with (McClelland, 1980; Schultheiss, 2008; Spangler, 1992). Implicit motive measures are particularly good at predicting non-declarative criteria, such as instrumental conditioning, stimulus-driven attentional processes, and nonverbal communication (i.e., behavioral criteria frequently employed in biopsychological and psychoendocrinological studies of motivation in humans and animals), but not at predicting declarative criteria, such as social judgments and attitudes, the choice and setting of goals, or making decisions. In contrast, explicit motive measures are well-suited for predicting the latter criteria, but not for predicting non-declarative criteria (Schultheiss, 2008).

In the following, I will review the hormonal correlates of the three implicit motives most frequently studied and for which physiological correlates have been clearly documented, that is, the need for power (n Power), a concern with having impact on and dominating others; the need for affiliation (n Affiliation), a concern with establishing, maintaining, or restoring close and friendly relationships; and the need for achievement (n Achievement), a concern with mastering challenging tasks. This is not a conclusive list of basic motivational needs with biological roots; the hormonal correlates of other implicit needs as assessed by PSE, such as the needs for food, sex, or variety (Atkinson, & McClelland, 1948; Clark & Sensibar, 1958; Maddi & Andrews, 1966), still remain to be explored. To explain why hormones should be considered in the context of research on implicit motives in the first place, I will start by providing some background on the central role of the hypothalamus in the regulation of motivational and endocrine processes.

Why Hormones?

To better understand the significance of hormones in motivational processes, it is important to realize that hormone release is regulated by the hypothalamus, which is situated at the base of the forebrain, surrounding the third ventricle. It is one of several key structures of the motivational brain, which also includes the basal ganglia, the orbitofrontal cortex (OFC), and the amygdala, and has particularly extensive connections with the latter two structures (see Rolls, 2005; Schultheiss & Wirth, 2008). However, in contrast to these other structures, which serve more ''general-purpose'' functions of motivation (see Schultheiss & Wirth, 2008) such as incentive prediction (amygdala), response selection and energization (basal ganglia), and incentive evaluation (OFC) and that apply more or less to all motivational needs, the hypothalamus is a critical neuronal substrate for the

specificity of these needs. This is most apparent in its structural and functional architecture: It consists of several anatomically distinct nuclei that serve different motivational functions such as sleeping and waking, drinking, feeding, dominance, social affiliation, sexual reproduction, and parenting (Becker, Breedlove, Crews, & McCarthy, 2002; Nelson, 2005; Panksepp, 1998). Evidence for a specific role of hypothalamic nuclei in motivation comes from animal studies in which lesioning and electrical stimulation of specific nuclei lead to the abolishment or augmentation, respectively, of a given motivational need as manifested in the performance of need-specific behavior, particularly its consummatory aspects. For instance, the anterior nucleus of the hypothalamus is critical for aggressive dominance (reviewed in Albert, Jonik, & Walsh, 1992; Delville, DeVries, & Ferris, 2000; and Sewards & Sewards, 2002). Electrical brain stimulation in this hypothalamic area elicits dominant posturing and affective attack behavior in male rats. The effect can be augmented by administration of testosterone and vasopressin directly into the anterior nucleus and reduced by administering substances that counteract the effect of these hormones. A specific role of the anterior hypothalamus in dominance can be deduced from the fact that lesions of this area abolish the motivation to dominate conspecifics, but leave other motivational drives intact, whereas lesions of other hypothalamic nuclei in turn leave dominance motivation intact.

The existence of several hypothalamic nuclei with different motivational functions reflects evolutionary forces that have required the development of specialized systems for the successful mastery of distinct and recurrent problems of survival, such as thermoregulation, proper hydration, maintaining a safe level of nutrients, being protected by a social group, sexual reproduction, etc. It behooves a motivational psychologist to know about the various hypothalamic nuclei and their functions in order to better understand the biological roots of those motivational systems that have existed in mammals long before the advent of language and the associated possibility of directing one's behavior through words.

The hypothalamus represents not only the seat of evolved motivational needs, it also controls the endocrine system (Iversen, Iversen, & Saper, 2000). Several hypothalamic nuclei release hormones either directly into the blood stream, via the posterior part of the pituitary, or into the brain, where these hormones act like neurotransmitters, altering the function of neurons (see Figure 1). The neuropeptide hormones oxytocin and vasopressin are secreted in this way, exerting transmitter effects in the brain and endocrine effects in the body, where they influence target organs such as the uterine wall or the milk-producing glands in the breast. The hypothalamus also controls hormone release in the body indirectly, by secreting regulatory hormones into the bloodstream via the anterior pituitary. These regulatory hormones then stimulate release of hormones from glands in the body, such as the adrenals (e.g., cortisol) or the gonads (e.g., testosterone, estradiol, progesterone).

A well-known example of the hypothalamic control of endocrine function is the case of the hypothalamic-pituitary-adrenal (HPA) stress axis. When an individual is confronted with a threatening or aversive stimulus, the paraventricular nucleus of the hypothalamus releases corticotropin-releasing hormone (CRH), which in turn triggers the release of the adrenocorticotrope hormone (ACTH) from the pituitary. ACTH travels through the bloodstream to the adrenals, where it stimulates the release of cortisol. Cortisol has a host of effects on the body that ensure that energy is available for coping with the stressor and will not be wasted for other, currently nonessential functions. But because cortisol is a steroid and therefore a very small molecule that can pass through cell membranes, it can also travel back to the brain where it provides feedback to the pituitary and hypothalamus, inhibiting the release of further CRH and ACTH if a critical level of cortisol has

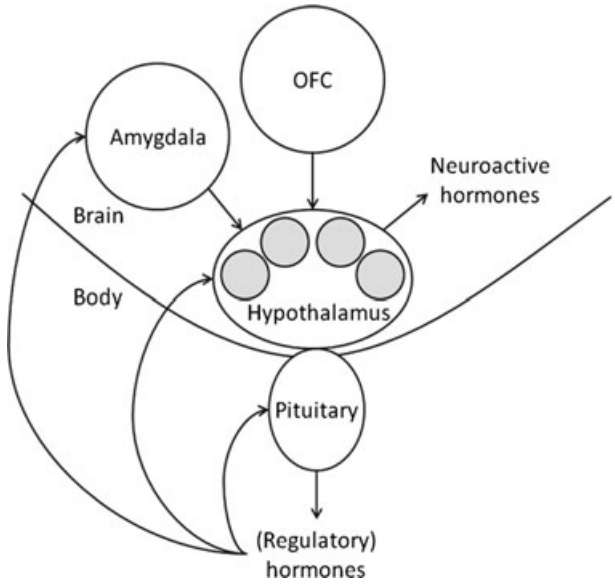

Figure 1 Schematic overview of the interplay between the hypothalamus (function-specific nuclei are indicated by grey circles), its regulation of the endocrine system, and its interaction with other motivational brain areas (basal ganglia not shown) through direct connections and endocrine effects. Hypothalamic regulation of hormone release is regulated through negative feedback loops, indicated by arrows from peripheral hormones to the hypothalamus and the pituitary. Feedback from peripheral hormones also affect functions of other motivational brain areas, such as the amygdala (involved in Pavlovian conditioning and responses to conditioned cues; LeDoux, 1996), the orbitofrontal cortex (OFC, involved in hedonic evaluation of reinforcers; Kringelbach, 2005), and the striatum (not shown here; involved in behavioral reinforcement; Frye et al., 2002).

been reached in the body. The HPA axis therefore provides an example for a negative feedback loop of hormone release that is typical of most endocrine systems.

And, as I have illustrated with the example of the anterior hypothalamus and aggressive dominance, the hypothalamus is full of receptors for hormones whose release elsewhere in the body it controls. For instance, the hypothalamus's medial preoptic area, a key structure for female parental motivation, has receptors for estradiol and progesterone. Levels of these two gonadal hormones increase dramatically during pregnancy and, through their effects on receptors, prime the medial preoptic area for maternal behavior. If these receptors are blocked, motivation of rat mothers to care for their pups is blocked, too (see Young & Insel, 2002). Thus, the motivational and endocrine functions of the hypothalamus are closely intertwined: motivational systems centered in this brain area influence hormone levels in the body, and changing hormone levels in the body in turn influence motivational functions of the hypothalamus.

The hypothalamus also interacts, either through direct connections or through endocrine effects, with other areas of the motivational brain. Endocrine and autonomic responses regulated by the hypothalamus can come under the control of conditioned stimuli through projections from the amygdala and of the hedonic value of reinforcers through projections from the OFC (reviewed in Rolls, 2005). Endocrine changes regulated by the hypothalamus in turn affect responses in other motivational brain areas (for reviews, see Becker et al., 2002; and Nelson, 2005). For instance, high testosterone levels attenuate amygdala responses and increase OFC responses to dominance signals in humans (Stanton, Wirth, Waugh, & Schultheiss, 2009). Animal studies also demonstrate that testosterone influences instrumental learning and reinforcement through its effects on the

striatum (e.g., Frye, Rhodes, Rosellini, & Svare, 2002; Packard, Schroeder, & Alexander, 1998).

This brief review of the dual role of the hypothalamus in motivation and endocrine regulation underscores the importance of hormones as central indicators of motivational processes. Their release directly reflects specific motivational functions of the hypothalamus and indirectly the effects of other motivational-brain areas on the hypothalamus. Changing hormone levels in turn change the function of brain areas responsible for the regulation of motivational functions, such as responding to conditioned cues (amygdala), instrumental behavior (striatum), and hedonic evaluation of reinforcers (OFC; see Schultheiss & Wirth, 2008).

Hormonal Correlates of n Power

Research support for involvement of stress hormones and gonadal steroids in n Power is solid. Work by McClelland and colleagues has accumulated evidence that hormones secreted by the sympathetic nervous system (SNS), such as epinephrine and norepinephrine, are elevated in individuals high in n Power, particularly after exposure to power stressors such as exams or incarceration (reviewed in Jemmott, 1987; and McClelland, 1989). This research also suggests that n Power-dependent SNS activation is moderated by activity inhibition, a measure of individuals' propensity to engage right-hemispheric functions during stress (Schultheiss, Riebel, & Jones, 2009): Overall, power-motivated individuals high in activity inhibition tend to show the strongest hormonal responses to stress, a finding that is consistent with the right hemisphere's key role in SNS activation (see Wittling, 1995).

More recent work by Wirth, Welsh, and Schultheiss (2006) also implicates the HPA axis in stressed power motivation: n Power predicted cortisol increases after losing a dominance contest against another person, but not after winning, and this effect emerged for women and men alike and across samples from two different countries (Germany and the US).

Because the gonadal steroid hormone testosterone is notorious for its association with inter-male aggression and other behavioral expressions of social dominance in males of many species (see reviews by Mazur & Booth, 1998; Wingfield, Hegner, Dufty, & Ball, 1990), my colleagues and I have explored the association between this hormone and n Power in men for more than a decade (see Schultheiss, 2007; and Stanton & Schultheiss, 2009; for reviews). Our findings can be summarized as follows: First, the cross-sectional association between testosterone and n Power in men is positive, but weak (see Table 1 for an overview of relevant findings). This is not surprising, because n Power represents a latent motivational disposition whose effect on physiology and behavior should only be noticeable in the presence of suitable incentives, but not at other times, and the association may also be moderated by extraneous factors, such as time of day (see Schultheiss et al., 2005). Consistent with this dynamic view of motive-hormone relationships, participants' testosterone changes in response to experimentally varied dominance contest outcomes depended on their power motive level: in winners, n Power predicted testosterone increases, and in losers, it predicted either no change or testosterone decreases. As Table 1 shows, these effects emerged consistently across studies and with a large average effect size for winners. Across two studies (Schultheiss & Rohde, 2002; and Schultheiss et al., 2005; Study 1), contest-induced testosterone changes also mediated the effect of n Power on implicit learning of a visuomotor sequence during the contest and thus affected a type of learning that is mediated by the striatum (see Poldrack et al., 2001).

Table 1 Associations between n Power and testosterone (in men) and estradiol (in women) assessed cross-sectionally (baseline) and between n Power and hormone changes after winning or losing a dominance contest

		Baseline		Winners		Losers	
Study	Comment	*n*	*r*	*n*	*r*	*n*	*r*
Testosterone in men							
Dabbs, Hopper, and Jurkovic (1990)		57	0.20				
Schultheiss et al. (1999)	no-s Power participants	42	0.29	21	0.88[a]	21	0.54[a]
Schultheiss and Rohde (2002)	Low-inhibition participants	29	−0.04[b]	11	0.71	18	−0.08
Schultheiss et al. (2003)		18	0.44				
Schultheiss et al. (2005, Study 1)		87	0.00	41	0.21	46	−0.38
Weighted average *r*		233	0.13	73	0.57	85	−0.09
Estradiol in women							
Schultheiss et al. (2003)	Single women	13	0.54				
Stanton and Schultheiss (2007)	Single women/low estradiol CV	25	0.55	16	0.35	9	−0.42
Stanton and Edelstein (2009)	Single women	20	0.48				
Weighted average *r*		58	0.52				

Note. [a]Only raw correlations between post-contest testosterone and n Power reported. [b]Association between testosterone and n Power not reported in paper, but calculated from original data. All correlation coefficients were transformed to Z′ scores before averaging.

Drawing on work by Sapolsky (1987) on stress and testosterone release in dominant and non-dominant primates, I have proposed a psychophysiological model that integrates findings related to stress hormone and testosterone release in power-motivated men (Schultheiss, 2007; Stanton & Schultheiss, 2009). According to the model, n Power predicts cortisol and SNS hormone increases in response to dominance challenges. Because both types of stress hormones have a quick and direct effect on testosterone release from the testicles, although in different directions, the net outcome in terms of testosterone increase or decrease depends on whether the challenge is mastered or not. If the person succeeds and successfully establishes dominance, SNS hormones' stimulating effect on the testicles prevails over the inhibiting effect of cortisol, leading to a quick net increase in testosterone. If, on the other hand, the person fails and is exposed to subordination stress, the inhibiting effect of increasing cortisol levels prevails over the effect of SNS hormones, leading to a net decrease in testosterone. Although the model integrates existing findings into a physiological framework that is consistent with the literature on primates (Sapolsky, 1987), so far it has not been tested as a whole by assessing the course of all three hormonal parameters – testosterone, cortisol, SNS hormones – simultaneously over the course of winning or losing a dominance contest.

Because in women testosterone is predominantly released by the adrenals, as a byproduct of HPA axis activation, and not the gonads, this hormone was not expected to covary with n Power in the same way as it does in men. Schultheiss et al. (2005) report that women's n Power predicts testosterone increases in response to a dominance challenge, regardless of whether the challenge results in a victory or a defeat. This finding is in agreement with the hypothesis that power-motivated individuals show stronger stress responses to dominance challenges, although it diverges from Wirth et al. (2006) observation that power-motivated women, like men, show differential cortisol responses to dominance contest outcomes.

Moreover, Stanton and Schultheiss (2007) were not able to replicate the effect of n Power on testosterone responses to a dominance contest. Thus, despite some evidence that implies testosterone in n Power in women and the observation that testosterone is linked to dominant behavior in women (e.g., Dabbs & Hargrove, 1997; see also the review by Mazur & Booth, 1998), more research is needed to better understand the functional role of testosterone in female power motivation.

Estradiol, which is released from the ovaries but also converted from testosterone elsewhere in the male and female body, is a likelier candidate for the role of a "female dominance hormone". Research on mammals, including primates, suggests that dominant females have higher estradiol levels than subordinate females (e.g., Carlson et al., 2004; Faruzzi, Solomon, Demas, & Huhman, 2005) and that estradiol plays a causal role in female dominance behavior (see Michael & Zumpe, 1993; for a review). Consistent with these observations in animals, Schultheiss, Dargel, and Rohde (2003) observed that single women's estradiol was positively associated with n Power around menstruation, that is, at a time in the cycle when stable individual differences in basal levels of estradiol can be measured. As shown in Table 1, the association between n Power and estradiol in single women has been replicated twice since Schultheiss et al.'s original study, and with consistently large effect sizes. Additionally, Stanton and Schultheiss (2007) showed that estradiol has a functional relationship with female n Power that parallels the one observed for testosterone with male n Power. In women who won an experimentally manipulated dominance contest against another woman, n Power predicted post-contest estradiol increases, whereas in losers, n Power predicted post-contest estradiol decreases. Remarkably, the joint effect of contest outcome and n Power on baseline-residualized changes in estradiol could still be detected 24 hours after the contest. In summary, these studies and findings support a key role of estradiol in women's power motivation. What needs to be resolved, however, is what drives the relatively quick estradiol changes in response to a dominance contest observed by Stanton and Schultheiss (2007) and what effects these changes have on affect, cognition, and behavior.

Hormonal Correlates of n Affiliation

Early evidence for psychophysiological correlates of n Affiliation came from research on immune system responses to stress (for summaries, see Jemmott, 1987; McClelland, 1989). In these studies, n Affiliation predicted better immune system functioning and lower likelihood of illness, particularly if stress or activity inhibition were low, too. More direct evidence for a link between n Affiliation and endocrine functioning came from a study in which students' hormonal responses to an academic examination were tested (McClelland, Ross, & Patel, 1985). Compared to other students, individuals whose n Affiliation exceeded their n Power responded only with a slight increase in salivary norepinephrine, an indicator of SNS activation, to the exam and recovered quickly after the exam was over. Unfortunately, the specific effect of n Affiliation on hormone secretion was not reported in this study, which makes it somewhat difficult to disentangle the contributions of n Affiliation and n Power. But it is consistent with the observation in a longitudinal study that over time, n Affiliation is associated with decreases in systolic and diastolic blood pressure, that is, cardiovascular measures that reflect the impact of adrenal stress hormones (McClelland, 1979). Taken together, these findings suggest a link between high n Affiliation and a dampened SNS response and, by inference, perhaps an increased response of the parasympathetic nervous system (PNS), to challenges and stressors.

Another line of research implicates the gonadal steroid hormone progesterone, which is released from the ovaries (women) and adrenals (both genders), in implicit affiliation

motivation. Progesterone has sedative and anxiolytic effects through its action on GABA receptors in the brain (the same receptors that are targeted by sedatives like valium) and counteracts the effects of stress hormones like cortisol (Wirth, 2011). Schultheiss et al. (2003) observed that n Affiliation scores were higher in women who were taking oral contraceptives, which usually contain progesterone-like substances, than in normally cycling women or in men. In addition, they also found that in normally cycling women, higher progesterone levels around ovulation predicted higher n Affiliation in the subsequent luteal phase of the menstrual cycle, suggesting a causal effect of progesterone on affiliation motivation. To further elucidate the relationship between n Affiliation and progesterone, Schultheiss, Wirth, and Stanton (2004) experimentally aroused this motivational need by presenting a romantic movie and measured participants' progesterone changes from before to after the movie. Compared to a neutral-movie control condition and a power-arousing movie condition, participants who had watched a romantic movie not only showed increased PSE affiliation motive scores but also higher progesterone levels after the movie. This suggests that arousal of affiliation motivation can also lead to increased progesterone release. A study by Wirth and Schultheiss (2006) that also used movies to study effects of aroused n Affiliation on progesterone provided a partial replication for this effect: regardless of the movie presented, participants' net increases in progesterone were associated with net increases in n Affiliation from before to after the movie. Other research building on this work has provided further evidence for a role of progesterone in close, affiliative contact (Brown et al., 2009) and in coping with social rejection (Maner, Miller, Schmidt, & Eckel, 2010).

In summary, these findings suggest that affiliation motivation and progesterone release have bidirectional links: progesterone, either fluctuating naturally or taken as contraceptive, can prime affiliation motivation, and arousal of n Affiliation can in turn lead to the release of progesterone. Wirth (2011) speculates that in the presence of stressors, increased progesterone and associated increases in affiliation motivation can have positive effects on health directly through down-regulation of stress responses and indirectly through social-support seeking (see also Taylor, 2006, for related arguments concerning oxytocin, another likely, but so far unexplored hormonal correlate of n Affiliation). This argument is consistent both with the observed role of n Affiliation in SNS/PNS functioning and illness and, of course, with the amply documented function of this motive as a drive for close social contact.

Recent research suggests that progesterone-mediated affiliation with others may come at a cost for the self, however. Schultheiss, Patalakh, and Rösch (2012, for, publication) found increased progesterone levels to be associated with several indices of cognitive and motivational dissociations. Most importantly, they observed that the higher individuals' progesterone level, the higher was the degree of incongruence between their implicit motives and the types of goals they pursued in their daily lives. While these findings suggest that elevated progesterone is associated with an increased likelihood of adopting and pursuing goals that are alien to one's motivational self, more research is needed to substantiate this conclusion.

Hormonal Correlates of n Achievement

Although n Achievement represents the oldest and most well-researched motive, least is known about its hormonal correlates. Some clues point towards a role of the neuropeptide vasopressin, which is released from the pituitary and regulates water retention in the body and memory processes in the brain, but also social bonding and aggression in many mammalian species (Insel & Young, 2001). McClelland (1995) reports that he and his collaborators observed in two studies on the role of n Power and norepinephrine in

memory formation that participants high in n Achievement provided urine samples with smaller volumes than those low in n Achievement. To follow up on these observations, McClelland (1995) conducted a study in which he experimentally manipulated achievement arousal for a memory task which involved remembering a story and assessed, in addition to n Achievement, urine sample volume and story recall one day after the experimental manipulation. For participants in the achievement-arousal condition, but not in the control condition, n Achievement predicted lower urine sample volume and better recall for achievement-related facts from the story. Urine sample volume mediated the effect of aroused n Achievement on story recall. For McClelland (1995), these findings were consistent with the hypothesis that for individuals high in n Achievement, achievement arousal increases vasopressin release, which in turn attenuates urine secretion and enhances episodic memory. McClelland conducted a follow-up study in which vasopressin was actually measured in urine samples and which yielded evidence both of a substantial positive correlation between levels of this hormone and n Achievement and of their interactive effects on memory recall after experimental arousal. However, this study was never published (see Schultheiss, 1997). Thus, the hypothesis that n Achievement is related to vasopressin remains largely untested, but intriguing.

Future Directions

In describing the current state of research on the endocrine correlates of implicit motives, I have already identified some specific areas for future research. In closing, I will take a bird's eye perspective and suggest three more general directions in which this type of research could be taken. First and foremost, the issue of causality needs to be resolved. This can be done by following the approach originally championed by McClelland and colleagues in their validation studies of implicit motive measures: a motivational state is experimentally aroused and its effects on hormone changes and mental content, as reflected in PSE stories, are studied. This was, in fact, the approach that Steele (1973; see also McClelland, 1987) took in the very first study on the link between motives and hormones. He aroused power motivation, achievement motivation, or nothing at all and studied the effects of these manipulations on changes in n Power, n Achievement, and urinary excretion of norepinephrine and epinephrine. Only power arousal led to increases both in n Power scores and norepinephrine, and both increases were strongly correlated ($r = .66$). The studies by Schultheiss et al. (2004) and Wirth and Schultheiss (2006) represent variations of this type of study design. It is relatively easy to implement for a behavioral scientist and allows conclusions about the causal effects of motivational arousal on measures of hormones and motives simultaneously, thus testing the validity of both types of measures as indicators of motivation.

But causality can also be established through the reverse approach, by manipulating hormone levels and studying the effect of this intervention on changes in implicit motive measures. Hormone levels can be experimentally altered through a variety of means (e.g., nasal sprays, transdermal patches, pills) and their effects compared to a suitable unmedicated control group (see van Honk, 2009, for an overview of experimental manipulations of hormone levels). So far, this approach has not been used in research on the endocrine correlates of implicit motives, probably due to the higher hurdles involved in getting such studies approved by institutional review boards and collaborating with medical researchers who are allowed to administer drugs. Still, this approach has the potential to yield insights into the causal effects of hormones on implicit motives. Of course, such evidence would not rule out the possibility of causal effects of motive arousal on hormone levels – as pointed out previously, the relationship between hormones and behavior (including motivation) is often bidirectional.

A second fruitful avenue for future research on motives and hormones is the study of the interplay between hormones and their receptors. In a sense, hormone levels are just one half of the picture; the receptors they bind to and through which they can affect neurons and eventually behavior represent the second half. Receptors vary in their sensitivity to the hormones they are associated with, and this variability can be traced back to gene polymorphisms. Thus, assessing genetic markers of receptor sensitivity in addition to hormone levels represents an important and promising extension of current research on the endocrine correlates of motives. For instance, research on androgen receptor (AR) polymorphisms shows that variants of the AR act as a moderator of the effect of testosterone: one AR variant is less sensitive and effectively prevents testosterone from having any impact on behavior, while another variant is more sensitive and thus allows testosterone to exert its full effect (Seidman, Araujo, Roose, & McKinlay, 2001). Such receptor x hormone interactions may be the reason for some of the variability in the association between n Power and basal testosterone, as presented in Table 1. For instance, it is possible that basal testosterone is consistently and positively associated with n Power in men with the sensitive AR variant, but not in those with the other variant. Without assessing AR variability, this lawful motive-hormone relationship could not be properly examined and documented, however.

Finally, a third direction into which research on motives and hormones could be taken deals with the mechanisms behind the association between both and brings us back to the motivational brain. To advance our understanding of the behavioral endocrinology of implicit motives, studies are needed that examine the relationship between implicit motives, activation of motivational brain areas (e.g., Schultheiss et al., 2008), changes in hormone levels, and behavior. For instance, one straightforward prediction from the literature on motives and hormones is that individuals high in a given motive (e.g., n Power), if exposed to motive-arousing stimuli or tasks (e.g., viewing angry faces), should show stronger activation of the hypothalamic area. Although, given its small size, imaging the hypothalamus represents a challenge for researchers and the resolution of currently available techniques is too coarse to differentiate individual nuclei within this brain structure, brain imaging studies have already demonstrated that individual differences affect hypothalamic activation responses to suitable stimuli (e.g., Bartels & Zeki, 2004; Holsen et al., 2011). Therefore, the logical next step would be to examine whether individual differences in implicit motives yield similar activation differences in the hypothalamus in response to suitable stimuli and whether such differences are also associated with subsequent hormone changes and behavior. As I have argued at the beginning of this section, the design can also be reversed by administering hormone versus placebo and studying the resulting differences in brain activation in response to motivational stimuli and in thematic content of PSE stories (see Hermans, Ramsey, & van Honk, 2008, for effects of acute hormone administration on activation differences in the hypothalamus, OFC, and amygdala).

To conclude, the study of the associations and interactions between implicit motives and hormones has already yielded substantial evidence for close links between both phenomena and holds considerable promise for new insights into the neuroendocrine basis of implicit motives.

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Short Biography

Received his diploma (1994) and PhD (1996) from Friedrich-Alexander University, Erlangen, Germany. From 1997 to 1999 post-doc at Harvard University, Boston, USA and University of Potsdam, Potsdam, Germany. Assistant professor (2000–2005) and associate professor of psychology (2005–2007) at the University of Michigan, Ann Arbor, USA. Since 2007 professor of psychology at Friedrich-Alexander University, Erlangen, Germany. Current areas of research: endocrine correlates of implicit motives; effects of implicit motives on brain activation, cognitive, and behavioral responses to perceived facial expressions of emotion; factors influencing and outcomes influenced by the interplay of implicit motives and explicit goals and values. For more information, please visit the Human Motivation and Affective Neuroscience Laboratory website at http://www.psych2.phil.uni-erlangen.de/~oschult/humanlab/index.htm.

Endnote

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Appendix

Sample PSE picture, story, and coding (see Schultheiss & Pang, 2007, for details).

These are two lovers spending time at their favorite bridge (n Affiliation). The guy is trying to convince his girlfriend (n Power) to follow him to California, where he wants to enter graduate school. The woman already has a successful career (n Achievement) as a ballet dancer in Boston and has become quite famous (n Power). The two try to find a solution that will allow them to continue to stay together as a couple (n Affiliation). Eventually, they will find a compromise that enables both of them to have successful careers (n Achievement) and be in each other's company as much as possible (n Affiliation).