

**EXAMINING THE ROLE OF ENDOGENOUS OPIOIDS ON ATTACHMENT AND
SOCIOSEXUALITY USING THE FRAMEWORK OF EVOLUTIONARY LIFE
HISTORY THEORY**

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Abstract

Evolutionary life history theory has been used to examine individual differences in attachment and sociosexuality within adult romantic relationships. One proposed mechanism for the variation observed within individuals is the endogenous opioid system. Through the use of testosterone, endogenous opioids may cause decreases in mating effort and increases in parental care of long-term partnered persons. Using the framework of evolutionary life history theory, this review examines current literature on opioids, attachment, sociosexuality, and testosterone, and attempts to evaluate the potential role of the endogenous opioid system as the key underlying mechanism, which uses testosterone to mediate differences in adult romantic attachment and sociosexuality.

Introduction

The endogenous opioid system has received much attention and extensive research for its effects on reward and pain. However, one area of which the system has not received as much consideration is the role opioids play in regulating attachment and sociosexuality. This study intends to evaluate the possible role endogenous opioids play, through the use of testosterone, on attachment and sociosexuality. Sociosexuality refers to the willingness of a person to engage in uncommitted, short-term sexual relationships (Jackson and Kirkpatrick 2007). Numerous studies have already demonstrated the relationship between insecure attachment styles and behavioral problems and mental disorders in humans (Chen 2017; Greenberg et al. 1933). Improved understanding of opioids and their effects will have significant applications for a broad range of clinical situations, such as better assessing and treating young children in schools with disruptive disorders (Greenberg et al. 1933). While some research has already examined the brain opioid hypothesis of social attachment (BOSTA), suggesting that opioids are a key implementer in primate and human bonding (Machin and Dunbar 2011), this paper focuses on evaluating the effect of opioids using the framework of evolutionary life history theory and incorporating the role of testosterone into this process. It is predicted that opioids affect testosterone levels, which in turn mediates attachment and sociosexuality.

Evolutionary life history theory examines the tradeoffs that take place between varying strategies in species and individuals for fitness success (Kaplan and Gangestad 2005). Tradeoffs can be between somatic and reproductive effort, and within the strategy of reproductive effort, resources can be devoted to either mating for more offspring, or parenting of already conceived offspring (Geary 2002). One way the tradeoff between mating and parenting effort is demonstrated is through individual differences in romantic attachment styles of adults.

Attachment styles vary between individuals, with some exhibiting secure attachment and others having insecure attachments that are either avoidant or anxious (Del Giudice 2009). This variation in attachment styles is an adaptive trait to increase success in one's environment, resulting from early life experiences. Opioid levels have been suggested to underline individual differences in attachment styles (Nummenmaa et al. 2015). One way opioids may be influencing attachment and sociosexuality is through the use of testosterone. Testosterone increases mating effort, and so to allow for long-term monogamous relationships, testosterone levels must drop in a partnered individual (Roney and Gettler 2015). Studies have shown that partnered individuals, especially fathers, experience drops in testosterone to allow for an increase in parenting effort (Gettler et al. 2011), and that single individuals have higher levels of testosterone than partnered individuals do (van Anders and Goldey 2010). Interestingly, opioids have been shown to reduce testosterone levels in rodents (Pfaus and Gorzalka 1987). If endogenous opioids are a mechanism for fluctuating testosterone levels, then they can consequently be the mechanism behind the relationship between mating effort and parenting effort, and possibly attachment and sociosexuality in general.

1. Evolutionary Life History Theory

Life history theory is a meta-theory originating from evolutionary biology that seeks to study the relationships between mortality, growth, development and reproduction (Stearns 1992) as they can help to explain variation in size at birth, growth rate, age and size at sexual maturity, parity, the number of offspring produced, life span and mortality rates across species. One of the central tenets of life history theory is that resources available to an organism, and thus contributing towards that organism's fitness, are limited and consequently organisms must

selectively distribute those resources in a way that best increases overall reproductive success. For example, energy invested in growing a large body cannot be simultaneously invested in growing a strong immune system or towards reproduction. Life history theory looks at the strategies various organisms and species choose for allocating these resources throughout their life span in order to maximize their reproductive fitness (Quinlan 2007).

This allocation problem produces two types of trade-offs: current versus future reproduction and quantity versus quality of offspring (Kaplan and Gangestad 2005). The current versus future reproduction represents the decision of when an organism should become sexually mature. If current conditions are not optimal for successfully growing new offspring, investing in reproduction would certainly be a waste of resources. In this condition, natural selection should favor organisms that grow slowly and postpone reproduction. However, if future conditions are very risky then it pays to grow faster and reproduce earlier. The same argument can be applied to the other type of trade-off, the quantity versus quality of offspring. In ecologies characterized by high adult mortality, natural selection should favor a life history strategy characterized by a parent producing a larger amount of offspring of lower quality (smaller size-a consequence of the resource constraints) because in doing so it increases the chances that at least a few will survive and reproduce. However, when conditions are stable and the population is dense, parents will benefit from investing in few offspring of higher quality since as adults they will face higher challenges from conspecifics (Kaplan and Gangestad 2005).

Depending on ecological factors, most importantly mortality risk, species can be placed on a fast-to slow life history continuum. An organism with a slow life history strategy is recognized by low infant mortality rates, slow development, generally few offspring, and high parental investment (Figueredo et al. 2006). In contrast, organisms utilizing a fast life history are

characterized by early maturity, many offspring, and low parental investment. The variation in life history strategies is also present within species where individuals are distributed on the slow to fast continuum as well. The inter-individual variation in life history strategies depends on the type of environment that the individual has experienced during development.

For example, cues derived from growing up in a harsh environment characterized by low parental investment can be used by the infant as a measure of what type of future socioecology to expect. Will there be high mortality risk or will it be a safe one? The early information can then shape the infant's life history strategy and, consequently, the child's reproductive strategy later in life. In harsh conditions life history theory predicts that individuals should coevolve clusters of biological, behavioral and psychological traits that maximize fitness through early puberty, higher competitiveness such as higher levels of aggression and risk taking, higher fertility and low investment in parenting behavior. Evolutionary biologists define these traits as representing an organism's reproductive effort, to distinguish it from the opposite strategy, which is characterized by somatic effort that results in more investment toward somatic growth, immune system and delayed reproduction (Caudell and Quinlan 2012).

This variation between individuals' life history strategies within a species is the result of a complex interaction between genetic variation and environmental conditions (McNamara and Houston 1996). Hence, life history theory predicts that, within the boundaries set by the evolutionary history of a species, an organism's phenotype can vary depending on environmental conditions, with susceptibility to these conditions being stronger during development.

Humans, which are characterized by a long juvenile developmental stage, comparatively late reproduction, higher reproductive fertility, and high parental investment (Del Giudice 2009), sit on the slow continuum of life history theory when compared to other species. While it is

somewhat unique in the animal kingdom to have both slower development and high fertility, this seems to be the result of the extensive alloparenting that characterizes our species throughout evolutionary history (Del Giudice 2009). Humans implement a type of cooperative breeding where others in the group such as grandparents, aunts, older siblings, etc. help partake in raising the younger children, and by doing so, give mothers the opportunity to invest resources towards reproduction (Del Giudice 2009), hence increasing their life long reproductive output. This complex sociodemographic condition underscores the importance of parental and kins' investment for infant's survival and morphological (large brain) and sociocognitive development (Kaplan et al. 2000; Geary 2002). It is also noteworthy that comparatively, among mammals, human fathers invest significantly in parenting (Gettler et al. 2011). Hence, it comes with no surprise that children and parents develop strong attachment (Bowlby 1988).

However, as previously discussed, parental investment is sensitive to environmental conditions often associated with mortality risk (Ellis et al., 2009). There is some evidence showing that in conditions of warfare and high pathogen load, parents tend to invest less in their offspring (Quinlan 2007) and consequently cue offspring regarding their future environment and best possible life history strategy to develop. Stressful environments like economic deprivation lead to harsher parenting styles and, consequently, children who view the world as untrustworthy and behave in opportunistic, risky ways (Belsky et al. 1991). Children who grow up in harsh, unpredictable households develop personality strategies for coping with a dangerous world (Cabeza de Baca and Ellis 2017). Another factor parental care can indicate to children is the reproductive structure of their environment. Children develop promiscuity and reproductive strategies based on their predicted sexual environment. Lowered paternal care may indicate a polygynous mating system in which monogyny should not be expected. However, highly

invested fathers who exhibit supportive paternal care may indicate to offspring that a strongly monogamous system is in place (Del Giudice 2009). In addition to other perspectives such as a behavioral approach, life history theory can be a fruitful framework to study individual differences in personality and behavior and is especially suited to explain the development of different types of attachment styles and their link with adult sociosexuality (Chen 2017).

2. Life History Theory, Attachment and Sociosexuality

Attachment theory describes the variety of bonding styles that individuals utilize throughout their life to modulate social relationships (Nummenmaa et al. 2015). An individual's attachment style develops at a young age, and later influences their future interactions and relationships with others. Secure attachment develops in children when their relationship with a parent is responsible and caring. This attachment type leads to healthy and enduring adult relationships. In contrast, attachment insecurity (anxious or avoidant) develops from inconsistent parental care and results in less stable and healthy relations (Gleeson and Fitzgerald 2014).

Attachment has an important role in the romantic bonds formed between adults. The two broad, continuous dimensions of adult attachment are described as anxious-ambivalent and avoidant, with secure being the low and healthy score for both (Hadden et al. 2013). Avoidant attachment styles evade intimacy and relations with others, whereas anxious-ambivalent attachments are characterized by dependence on the partner within their relationships (Feeney and Noller 1990). A meta-analysis on sex differences in romantic attachment found males to have higher avoidance and lower anxiety attachment than females, as well as anxiety attachment to peak during young adulthood and avoidance to increase with age (Del Giudice 2011).

Variation in infants' early social experiences leads to relatively lasting differences in adult romantic relationship styles. Retrospective studies showed that children with positive early family relationships later report secure romantic attachments as well as trusting attitudes towards others. In contrast, adults who reported lack of parental support growing up exhibited anxious romantic attachment styles (Feeney and Noller 1990). Likewise, adults with a secure romantic attachments view their parents positively, whereas adults with insecure attachment style view their parents less well (Gleeson and Fitzgerald 2014).

According to life history theory, children who grow up in harsh environments characterized by poor parental support are expected to develop a fast life history strategy characterized by unrestricted sociosexuality, while children that experience warm and supportive parenting should develop a slow life history strategy (Cabeza de Baca and Ellis 2017). Given the importance of attachment style for the success of a long-term romantic relationship, individual differences in life history strategies may be moderated by the type of attachment style they formed as infants (Cabeza de Baca and Ellis 2017; Chisholm et al. 2005). For example, the cluster of phenotypic traits associated with a slow life history strategy should be associated with the establishment and maintenance of healthy secure romantic relationships in adulthood (Belsky et al. 1991).

Bearing from life history theory, it has been suggested that the specific attachment style a person ultimately exhibits is primed to develop plastically in response to interactions with the environment throughout middle childhood (Del Giudice and Belsky 2010). These early rearing experiences later influence a person's adult romantic bonding strategies (Belsky et al. 1991), possibly through the effect of psychosocial stress (Ellis 2004). Life history theory suggests that stressful experiences, such as inconsistent household structure and rejecting-insensitive parenting during early development, signal to a child that the future environment is characterized by higher

mortality/morbidity rates and that long term romantic relationships may not be expected nor, in reproductive terms, functional (Del Giudice and Belsky 2010).

As previously discussed, mortality risk is a key factor since it determines the amount and type of investment that parents provide to their children (Chisholm et al. 1993; Quinlan 2007). As a consequence of high mortality/morbidity risk, poor parenting is associated with the development of a fast life history strategy characterized by a cluster of traits such as fast development, early sexual maturation, high risk taking/impulsivity and unrestricted sociosexuality. Unrestricted sociosexuality represents the willingness of a person to engage in uncommitted, short-term sexual relationships (Jackson and Kirkpatrick 2007). These types of short-term relationship are typical of people with an avoidant attachment style and suggest that attachment style may be the mediator of early life stressful experiences and reproductive strategies (Chisholm et al. 1993). For example, early stress in women is correlated with a younger age at menarche, younger age at first birth, insecure adult attachment, and a shortened expected lifespan (Chisholm et al. 2005). In contrast, a non-stressful environment during childhood promotes the opposite reproductive strategy, one with late reproductive development and secure healthy adult romantic relationships (Belsky 1997).

Supporting the idea that attachment styles represent different types of reproductive strategies, research showed that avoidant and anxious insecure attachment styles are related with individual differences in sociosexuality. More precisely, people with avoidant attachment styles tend to score high in measures of unrestricted sociosexuality while people with an anxious attachment style show the opposite (Chen 2017). There are sex differences in adult attachment styles. For example, dismissing attachment style was more correlated to sexual permissiveness in men than

in women, however these sex-specific differences are less pronounced in non-western cultures (Schmitt and Jonason 2015).

3. The Neural Mechanism Regulating Attachment: The Role of Opioids

Endogenous opioids are peptides produced in the body that bind to opioid receptors in the brain. These peptides play a variety of roles including, but not limited to, stress, pain, motivation, and attachment. Endogenous opioid peptides are expressed throughout the brain and can be broken down into three main classes: endorphins, enkephalins, and dynorphins. Synthetically produced opiates and opioids can often mimic the effects of endogenous opioid peptides. Endogenously produced opioid peptides play a role in the perception and regulation of pain as well as the addiction to naturally produced and synthetically generated opioids (Milligan 2005). While the endogenous opioids have been studied mostly within the context of pain modulation and drug addiction, the strong similarities of those systems with the reward and reinforcement of individual relationship bonds suggests that opioid receptors may play a distinct role in social bonding (Donaldson and Young 2016).

The mother-infant relationship is an incredibly crucial bond that forms to ensure infant survival (Barr et al. 2008). This attachment likely develops from a simple process of distress and gratification that strengthens the bond between the two (Panksepp et al. 1994). The strong attachment formed between mother and infant serves to both elicit care from the mother and maintain close physical proximity among them (Nelson and Panksepp 1998). Endogenous opioids have been postulated to play a role in mother-infant attachments due to the strong similarities seen between opioid addiction and social dependence (Donaldson and Young 2016). Studies have suggested that opioids play a positive role in social reward in a maternal context.

For example, naloxone treatment blocked opioid peptides within the brain and consequently increased rat pups' motivation for maternal care, showing that a decrease in opioids leads to an increase in desire for companionship (Panksepp et al. 1994).

Beyond the mother-offspring attachment, endogenous opioids have been found to influence social behavior in a variety of different animal models. Previous studies have demonstrated that the immediate, reflex-like distress vocalizations that follow being separated from others can be related to the endogenous opioids. These distress vocalizations were observed across many species including chickens, guinea pigs, kittens, puppies, monkeys, and humans. For example, when naloxone, an opioid antagonist, was administered to both guinea pigs and chicks, distress vocalizations doubled within a ten minute period (Panksepp et al. 1980). Further support for the connection between opioids and social distress lies in the fact that brain systems which mediate separation distress are shown to be confluent with known opioid brain systems (Panksepp et al 1980). In addition to distress following social separation, research has also shown that opioids are one of the chemicals which affect social behaviors such as physical proximity to others, increased play and maternal behaviors. Animals that receive opiates socially isolate themselves as seen by reduced time spent in proximity by rodents, reduced tail wagging by dogs, and decreased social grooming by monkeys (Troisi et al. 2011).

Endogenous opioids are a proposed neurochemical mechanism motivating attachments in romantic, paternal, and social relationships (Machin and Dunbar 2011). While there are a variety of endogenous opioid receptors, the μ -opioid receptor has seen a considerable amount of research regarding human relationships and attachment. Nunnenmaa et al (2015) found that low μ -opioid receptor levels were associated with the avoidant attachment style in human adults. This suggests that the endogenous opioid system is an important contender for the neuromolecular

mechanism underlying the differences between adult attachment styles (Nummenmaa et al. 2015). They also found that social touching modulates the μ -opioid system activity, possibly serving to help reinforce and maintain social bonds in human relationships (Nummenmaa et al. 2016). In rat pups, endorphins have been shown to play a strong role in motivating attachment to the mothers. For example, pups given the opioid antagonist naloxone failed to learn their mother's odor, hindering their bond with mother and consequently their survival (Machin and Dunbar 2011; Roth and Sullivan 2003). Additionally, a common polymorphism in the mu-opioid receptor gene (OPRM1) has been associated with variation in attachment and personality. Expression of the minor A118G gene allele causes a threefold increase in binding affinity for the endogenous opioid peptide beta-endorphin. Adults expressing the minor G allele had an increased tendency to become engaged in affectionate relationships, had lower scores of avoidant attachment, and experienced more pleasure in social situations (Troisi et al. 2011).

Endogenous opioids are best documented for their ability to blunt pain, a function that serves more broadly to counter stress within an individual (Valentino and Bockstaele 2015). The relationship between opioids and adult attachment styles is further supported by the opioid effect with pain, given that having insecure attachment styles has been shown to make an individual more predisposed for developing chronic pain and disability (Meredith et al. 2008). In addition, viewing an image of a romantic partner while experiencing physical pain led to greater activity in the ventromedial prefrontal cortex (VMPFC), a region implicated in safety signaling and fear extinction, and corresponded with reductions in pain (Eisenberger et al. 2011). While many experiments have examined opioids and their pathway regarding physical pain, their parallel relationships with emotional or social pain are just as relevant. Some studies have shown that endogenous opioids acting upon μ -opioid receptors not only lessened the distress of an animal

following social separation, but also promoted play in social situations between individuals. In humans, social rejection activated the μ -opioid receptor system in a similar way to that during physical pain, further supporting that emotional pain is regulated by the opioid pathway in the same way that physical pain is (Hsu et al. 2015).

The brain opioid hypothesis of social attachment (BOSTA) suggests that opioids are necessary for the maintenance of long-term romantic and social relationships (Machin and Dunbar 2011). Evidence for this hypothesis comes from studies by Master et al. and Younger et al., who demonstrated that social support, such as being in a romantic relationship, increases the threshold for experiencing pain. In one instance, both holding the hand of a loved one and viewing a loved one's picture had pain-decreasing effects (Master et al. 2009). The other experiment found that the pain relief experienced while viewing pictures of a romantic partner is associated with reward system activation, possibly indicating that this effect is mediated by higher levels of opioids in people socially attached (Younger et al. 2010).

BOSTA suggests that a decrease in opioid activity/levels as a result of social isolation/rejection should increase desire for social companionship, and alternately, increases in opioid system reduce the need for relationships (Troisi et al 2011). Obviously, these hypotheses are based on indirect measures of opioids system in humans, that is, by the association of self-reported pain and social rejection, romantic partner support and attachment style. In general, studies showed that insecure attachment is associated with chronic pain, however this may be especially true for people with an anxious-avoidant style (Meredith et al. 2008). Interestingly, a recent study showed that individuals with an avoidant (but not anxious) attachment style may be less effected by social rejection in the sense that the neural networks activated by this social experience do not overlap completely with the one typically associated with physical pain

(DeWall et al. 2012). In short, securely attached persons that tend to form long-term romantic relationships may be characterized by higher levels of opioids or by a more sensitive opioidergic system, while insecurely attached persons should be characterized by a less functional opioidergic system, although this may be more specific for different styles of insecure attachment.

4. Life History, Sociosexuality and Hormones: The Effects of Testosterone

One of the most important trade-offs in life history theory is the mating versus parenting effort. Investing into mating effort focuses one's resources on increasing the number of offspring they produce, while investing into parenting effort increases the quality of one's already conceived offspring (Kaplan and Gangestad 2005). The degree to which an individual invests parental care into their offspring is partly influenced by the extent that parental care will benefit and increase survival of the offspring (Quinlan 2007). In many species, the level of parental care given to offspring is unequal, with one sex investing more in parenting than the other does. This sex difference in parental care is partly due to differences in initial investment of the offspring (Kaplan and Gangestad 2005).

In humans, men often place more effort into mating than parental care due to their higher reproductive rates and low level of initial investment; however, individual differences do exist, with some men investing large amounts of resources into parenting as a facultative adaption (Del Giudice 2009). Varying levels of investment in offspring also relates to differences in sociosexuality. Unrestricted sociosexuality is possibly a coercive strategy used by some individuals to increase mating success (Chen 2017). Since human men, in general, are more heavily invested in mating than parenting, it is likely that they exhibit less restricted

sociosexuality than women do. One important regulator of mating versus parenting strategies is testosterone.

Testosterone has been postulated to play an influential role in promoting mating effort, with increased muscle mass, sperm production, courtship displays, same-sex aggression, and more (Roney and Gettler 2015). As would be expected, studies have shown that single men have higher levels of testosterone than partnered men do (van Anders and Goldey 2010). In women, change in progesterone negatively correlated with change in desire for their own partners and other men, suggesting a hormonal effect on sexual motivation, and so, an effect in investment in mating effort (Roney and Simmons 2016). Because of testosterone's stimulating effect on mate pursuit, it likely negatively affects long-term relationships in monogamous species such as humans; and so, monogamous romantic relationships require a decrease in testosterone levels in order for an individual to commit and restrict sociosexuality. Consistent with this idea, a longitudinal study done by Gettler and others showed that men who became partnered fathers experienced large declines in testosterone, and fathers who reported three or more hours of childcare per day had even lower testosterone (Gettler et al. 2011).

Testosterone levels are associated with variation in sociosexuality and adult romantic relationships. One possible role of testosterone is to encourage mate seeking and unrestricted sociosexuality in individuals. In contrast to the behaviors associated with testosterone influence, a monogamous romantic relationship requires a decrease in testosterone levels in order for an individual to commit in a long-term romantic relationship (Roney and Gettler 2015). In both men and women, restricted sociosexuality in a partnered relationship is associated with lower testosterone levels compared to being single (Van Anders and Goldey 2010). However, even in a partnered relationship, unrestricted sexual desires and behaviors are associated with higher

testosterone levels comparable to that of single people. Men who had a strong desire for uncommitted sexual activity and women who had frequent uncommitted sexual behavior while in a relationship both had higher testosterone levels like those of single persons (Edelstein et al. 2011), indicating that testosterone tracks a person's investment towards mating effort.

Testosterone levels within an individual are controlled by a variety of factors, one of which being the endogenous opioid system. One of the effects of endogenous opioids within the brain is to inhibit activity in the hypothalamic pituitary luteinizing hormone axis as well as affect the androgen dependent feedback control of luteinizing hormone elaboration by this axis. One example of this is the opioid antagonist naloxone, which has been shown to prevent testosterone's negative feedback inhibitions of serum luteinizing hormone (LH) in castrated male rats (Cicero et al. 1979).

The effects of chronic opioid drug use are described in a way that mirrors the stages of being in a romantic relationship (Machin and Dunbar 2011). Opioid drug use is often described as having a short euphoria stage, followed by prolonged relaxation and sense of well being, and causing a strong withdrawal when experiencing loss; these stages of opioid drug use can easily be used to describe the stages of sexual relationships (Pfaus and Gorzalka 1987). One of the common side effects of chronic opioid drug use is decreased sexual desire, function, and often anorgasmia, the inability to experience orgasm. Studies have shown that opioids suppress luteinizing hormone (LH) and testosterone in rodents (Pfaus and Gorzalka 1987). Moreover, it is known that heroin use suppresses LH and testosterone in humans. Given the involvement of opioids in attachment, it is suggested that endogenous opioids are the mechanism mediating the relationship between testosterone and pair bonding and possibly sociosexuality. This would

predict that increases in endogenous opioids cause a drop in testosterone levels, which in turn decreases mating effort and so results in reduced sociosexuality.

Discussion

The goal of this review has been to evaluate the current research on endogenous opioids, testosterone, attachment, and sociosexuality to determine their relationship and the possible mediation effect of opioids on the latter, while using the framework of evolutionary life history theory. The study indicates that there is significant evidence demonstrating the effect endogenous opioids have on testosterone, and so attachment and sociosexuality, within humans. Evolutionary life history theory helps explain the variations observed in adult romantic attachment styles by demonstrating how each style can potentially increase reproductive success in a variety of environments (Belsky 1997). Individuals develop their attachment style early on in life by evaluating what they can infer about their future reproductive environment (Belsky et al. 1991). Much of adult sociosexuality and romantic relationships is mediated by both attachment style and testosterone levels. Decreased testosterone levels are associated with decreased mating effort and increased parenting effort, an effect often observed in individuals in long-term partnerships (Gettler et al. 2011). Given the effect of increased opioids on reducing testosterone, and reduced testosterone with increased parental care and reduced sociosexuality, it is likely that the endogenous opioid system, through testosterone, is a key mediator in adult attachment and sociosexuality.

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