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Stress and the development of agonistic behavior in golden hamsters

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Abstract

Aggressive behavior can be studied as either offensive or defensive responses to a stimulus. The studies discussed in this review are focused on the peripubertal development of offensive aggression in male golden hamsters and its responsiveness to repeated social stress. Quantitative and qualitative changes in offensive responses were analyzed during this period. Quantitative changes in offensive responses were observed as decreased frequency of attacks. Qualitative changes were observed as changes in attack types, as animals reorient their attacks gradually from the face to the lower belly and rump. These developmental changes were altered by repeated exposure to social stress during early puberty. Daily exposure to aggressive adults during early puberty accelerated the qualitative development of offensive responses and the onset of adult-like offensive responses. In contrast, social stress had little effect on the quantitative changes associated with early puberty. However, social stress was associated with higher attack frequency during adulthood. These effects of stress during early puberty contrast with those observed with animals in late puberty. At that time, repeated exposure to aggressive adults inhibits offensive aggression. These data constitute the basis for a new theory on the development of agonistic behavior that includes the following hypotheses. First, it is hypothesized that mid-puberty is marked by a change in responsiveness to repeated social stress. As such, differences in stress responsiveness from social interactions are interpreted as a basic distinction between play fighting and adult aggression. Second, it is also hypothesized that a common neural circuitry mediates the activation of offensive responses during play fighting and adult aggressive interactions.

Keywords: Play fighting; Offensive aggression; Social stress; Puberty; Serotonin; Vasopressin

Aggressive behavior in golden hamsters

Aggressive behavior can be studied in a laboratory setting as a response to a stimulus. The aggressive response can be either offensive or defensive (Blanchard and Blanchard, 1977, 1988; Adams, 1979). Offensive aggression is characterized as an initiation of approaches and attacks by the subject toward the stimulus animal. Defensive aggression is performed in response to perceived threats or attacks by the stimulus animal. These different types of responses can be confused as animals may alternate between offensive and defensive responses during a social interaction. As such, discriminatory tests for aggression require very specific conditions favoring one type of aggressive response over the other. For example, the resident/intruder test is commonly used to observe offensive responses (Miczek, 1979; Blanchard and Blanchard, 1988). In this test, the subject is observed inside its home cage in the presence of an intruder. Then, the behavior of the resident can be identified as a response to a stimulus animal. However, the behavior of the intruder can greatly affect the outcome of the test. In order to favor offensive responses, it is necessary to use a nonthreatening stimulus animal, such as a younger, smaller, or submissive conspecific. In the following studies, all aggressive encounters were observed under a resident/intruder context with a submissive intruder that was smaller (ca. 20%) and younger than the resident. In this context, the resident can be predicted to be dominant (Drickamer et al., 1973), and its aggressive responses would be purely offensive.

The present studies were performed with golden ham-

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sters. Hamsters are ideal for studying offensive aggression. Male hamsters are territorial and solitary animals (Dieterlen, 1959; Johnston, 1985; Festing, 1986). In the laboratory, hamsters can be weaned around 25 days postnatally and isolated in their own cages. After a couple of days, they readily attack smaller conspecifics placed in their home cage, particularly if they have the same gender (Pellis and Pellis, 1988a, 1988b). Behavioral observations with hamsters are routinely performed during 10-min periods. Such periods are sufficient to establish clear dominant/subordinate relationships in this species (Ferris et al., 1987).

The behaviors recorded during agonistic encounters between hamsters are not limited to overt aggression. In addition to attacks and bites, hamsters also perform a stereotyped scent marking behavior called flank marking (Johnston, 1975, 1985). Hamsters have scent glands located on their flanks. During encounters with conspecifics, hamsters groom and rub their flanks vigorously on the walls of their cages. This behavior can also be elicited in the absence of stimulus animals by placing the subject in the home cage of a conspecific. Flank marking is a component of agonistic responding in golden hamsters and is most commonly performed by the winner of a fight (Johnston, 1975, 1985; Ferris et al., 1987). Often, we have observed that resident hamsters will engage in flank marking immediately after a successful attack. During repeated testing between the same individuals with established dominant/subordinate relationships, hamsters substitute flank marking activity for overt aggression (Ferris et al., 1987). As such, aggressive behavior is particularly adaptive to environmental conditions. In this case, social memory interferes with the activation of offensive responses, replacing them with flank marking responses. Obviously, other factors also influence the outcome of an agonistic encounter between two individuals. It can be argued that factors associated with emotional or motivational states also contribute to the modulation of offensive responding. These factors would likely interact with the neural circuitry controlling offensive aggression.

Over the past 15 years, studies have established a number of critical elements explaining the neural control of offensive aggression in golden hamsters. These studies cover two main topics: the neural sites and the neurotransmitters involved in the expression of offensive aggression.

In golden hamsters, two neurotransmitters play a critical role in the activation of offensive aggression. Vasopressin microinjected within the anterior hypothalamus or the ventrolateral hypothalamus facilitates the onset of offensive responses toward intruders (Delville et al., 1996b; Ferris et al., 1997). In addition, peripheral treatment with fluoxetine, a serotonin reuptake inhibitor, and central injections of serotonin receptor 1A agonist inhibit offensive aggression in golden hamsters (Delville et al., 1996a; Ferris et al., 1997, 1999; Joppa et al., 1997). Serotonin probably interacts with vasopressin at the level of the anterior hypothalamus (Ferris et al., 1997). The area contains vasopressin and serotonin receptors (Ferris et al., 1997, 1999). Treatment with fluoxetine inhibits the effects of vasopressin injections (Ferris et al., 1997). Microinjections of serotonin 1A receptor agonist directly into the anterior hypothalamus inhibit the effect of vasopressin in this area (Ferris et al., 1999). It is possible that other sites such as the ventrolateral hypothalamus are also sensitive to serotonin. However, this possibility has never been tested. The serotonin neurons projecting to the anterior hypothalamus have been identified within the dorsal and median raphe nuclei though retrograde tracing (Ferris et al., 1999). The location of vasopressin neurons involved in the expression of offensive aggression have not been located by retrograde tracing as most vasopressin neurons are located in the vicinity of the anterior hypothalamus in golden hamsters (Ferris et al., 1995). Nevertheless, in a recent study, the distribution of evoked c-*fos* immunoreactivity in animals after consummation of offensive responding was compared with animals exposed to an olfactory stimulus that initiated some of the components of agonistic responding including flank marking but falling short of attacks and bites (Delville et al., 2000). In this study, a higher proportion of vasopressin neurons expressing c-*fos* immunoreactivity was observed within the medial division of the supraoptic nucleus and nucleus circularis in animals that attacked and bit their intruder. These data indicate that these neurons release vasopressin in the neighboring anterior hypothalamus to control the expression of offensive responding.

In these studies, the anterior hypothalamus was a focal point in the control of offensive aggression by vasopressin and serotonin. Other sites such as the ventrolateral hypothalamus have also been involved in the control of offensive aggression by these two neurotransmitters (Delville et al., 1986a, 1986b). As such, it is possible that both serotonin and vasopressin act on a variety of sites forming a neural network controlling offensive aggression, but this hypothesis has not been tested. Nevertheless, it is likely that the anterior hypothalamus is at the center of a neural network controlling offensive aggression and integrating various inputs critical for its execution (Delville et al., 2000). A recent study with golden hamsters has shown that the anterior hypothalamus is at the center of a neural network of reciprocal connections (Delville et al., 2000). More importantly, some of the areas sharing reciprocal connections with the anterior hypothalamus showed enhanced evoked activity (as evidenced by enhanced c-*fos* expression) in association with the consummation of offensive aggression in golden hamsters (Delville et al., 2000). Hence, these data indicate the existence of a neural network controlling the activation of offensive aggression. These areas include the medial amygdaloid nucleus, particularly its posterodorsal portion, the ventrolateral hypothalamus, the dorsolateral part of the midbrain central gray, and parts of the bed nucleus of the stria terminalis. These connections support the role of these areas in the activation of offensive aggression in golden hamsters as evidenced by studies using microinjections, electrical stimulations, or lesions (Bunnell et al., 1970; Delville et al.,

1996b; Potegal et al., 1996). The neurochemical identity of the neurons involved in this circuitry has not been identified. It is likely that a variety of neurotransmitters could modulate offensive aggression through these areas. It is also important to note that most of these areas are rich in gonadal and adrenal steroid receptors (Sutanto et al., 1988; Li et al., 1993; Du et al., 1996; Wood and Newman, 1999). The presence of these receptors within the neural circuitry may be critical for mediating the effects of gonadal and adrenal steroids on offensive aggression.

Extensive individual differences can be noted during resident/intruder tests. Some individuals are consistently aggressive while others are consistently nonaggressive. These differences may be related to behavioral characteristics, such as impulsivity or emotional reactivity. Indeed, emotional reactivity has been associated with differences in aggressive behavior (although not necessarily offensive aggression but also dominance and defensive aggression) in other species, including humans (Brain, 1972; Davidson et al., 2000; Haller et al., 2001; Plusquellec and Bouissou, 2001; Plusquellec et al., 2001). Behavioral differences may also be explained through differences within the neural systems controlling offensive aggression. For example, as testosterone can facilitate offensive aggression (Payne 1973, 1974), individual differences in aggression could be related to individual differences in plasma levels of testosterone or testosterone metabolism. In the nervous system, individual differences in aggression could also be related to individual differences in serotonin and vasopressin. In humans, aggressive behavior has been associated with insensitivity to serotonin, lower serotonin, and higher vasopressin levels in the cerebrospinal fluid (Kruezi et al., 1990; Coccaro and Kavoussi, 1997; Coccaro et al., 1998). The cause of these differences could be genetic. A number of knockout lines of transgenomic mice have been found aggressive (for review see Nelson and Chiavegatto, 2001; Miczek et al., 2001). Some of these knockout lines involve specific neurotransmitters associated with aggressive behavior in mice. However, the causes of individual differences could also be related to environmental factors, particularly during development. To date, a number of environmental factors occurring during development have been associated with enhanced aggression in golden hamsters. In this species, these developmental factors include substance exposure (alcohol, anabolic steroids, cocaine), exposure to environmental contaminants (lead exposure), or stress (social subjugation during puberty) (Melloni et al., 1997; Delville et al., 1998; Ferris et al., 1998; Delville, 1999; Harrison et al., 2000). This review is focused on the effects of social subjugation during puberty. However, before detailing these effects it is necessary to address first the development of offensive aggression.

Development of agonistic behavior in golden hamsters

Hamsters initiate agonistic behavior around postnatal day 20. As soon as they are capable of coordinated movements juvenile hamsters initiate flank marking behavior and play fighting behavior (Goldman and Swanson, 1975; Schoenfeld and Leonard, 1985; Ferris, et al., 1996). As for offensive responding with adults, play-fighting behavior can be tested in a resident/intruder paradigm, with a resident animal exposed to a smaller and younger intruder (Pellis and Pellis, 1988a, 1988b). In most cases, the resident will initiate attacks on the intruder. However, there are significant differences in offensive responding between adults and juveniles. These differences are best described as quantitative and qualitative. Quantitatively, juveniles are a lot more active than adults during agonistic encounters and perform more attacks than adults (Goldman and Swanson, 1975; Pellis and Pellis, 1988a; Wommack et al., 2003). The frequency of attacks reaches a peak in juveniles around postnatal day 35 and then decreases steadily until stabilizing around postnatal day 47 (Wommack et al., 2003). Qualitatively, the pattern of attacks differs between juveniles and adults (Pellis and Pellis, 1988a, 1988b; Wommack et al., 2003). In hamsters, offensive aggression by adults is directed at the lower belly and rump. In previous studies, the majority of bites performed by adults were focused on the lower belly and rump (Pellis and Pellis, 1988a, 1988b). In contrast, attacks and bites seem to be initially targeted at the face and cheeks in juveniles during play fighting. Based on these data, it has been argued that aggression by adults and play fighting by juveniles constitute two separate types of behaviors (Pellis and Pellis, 1988b). However, animals exposed to attacks are often able to block bite attempts or push them away from their original target. Therefore, in our studies, we defined attacks as a combination of an approach immediately followed by the initial bite attempt (Wommack et al., 2003). We found this measure more reflective of the initial intention of the resident. In this case, several types of attacks can be observed in hamsters (Wommack et al., 2003). Attacks are directed at the face of the opponent, the side and flanks, lower belly or rump (Fig. 1). We looked at the relative occurrence of each type of attack during peripubertal development in male golden hamsters. We clearly observed that facial and check attacks are typical of offensive responses by juveniles (P-28), while lower belly and rump attacks are typical of offensive responses by adults (P-70) (Wommack et al., 2003). These observations confirmed earlier reports in hamsters (Pellis and Pellis, 1988a, 1988b). However, we also found that animals were most likely to perform side attacks during mid-puberty (P-45). These observations suggested three separate periods: a play-fighting period (face and check attacks), a transitional period (side attacks), and an adult period (lower belly and rump attacks). In addition, we also noted that juvenile hamsters flank marked after successful attacks during the play-fighting period as they do during the adult period. This association between offensive responding and flank marking in juvenile and adult hamsters suggests similarities in the neural mechanisms underlying the control of agonistic behavior across peripubertal development.

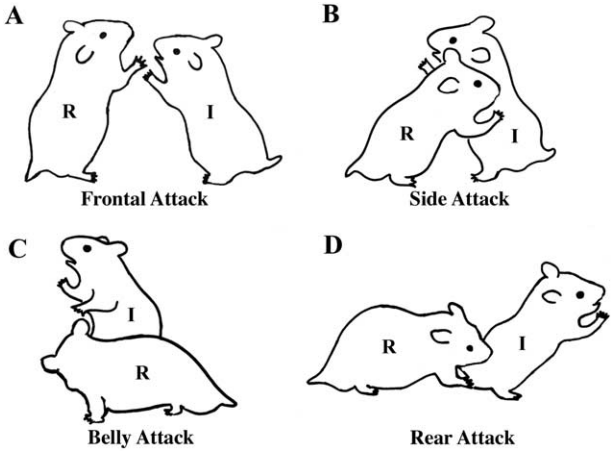

Fig. 1. Drawings representing different types of attacks by a resident (R) on an intruder (I). These different types of attacks are based on the initial target on the body of the intruder: the face and cheeks (A), the side and flanks (B), the lower belly (C), and the rump and rear (D). There attacks were classified as frontal attacks (A), side attacks (B), and belly/rear attacks (C,D).

Interestingly, little is known of the neural mechanisms controlling the activation of offensive responding in juvenile hamsters. In contrast, flank marking behavior has been extensively studied. Flank marking behavior, as offensive responding in adults, is controlled by an interaction between vasopressin and serotonin within the anterior hypothalamus (Ferris et al., 1984, 1997; Albers et al., 2002). The onset of flank marking, which coincides with the onset of play fighting, also coincides with a marked increase in vasopressin content within the anterior hypothalamus (Ferris et al., 1996). Therefore, we hypothesized that offensive responding by juveniles is also controlled by an interaction between vasopressin and serotonin in the anterior hypothalamus. We started testing this possibility by acute treatment with fluoxetine, a serotonin reuptake inhibitor. Single injections of fluoxetine inhibit aggressive behavior in adult male golden hamsters within 1 to 2 h. If serotonin is involved in the control of offensive responding in juveniles, a similar observation should be reported for play-fighting behavior. Indeed, we found an inhibition of offensive responding by juvenile male golden hamsters after a single injection of fluoxetine (20 mg/kg) (Fig. 2). This inhibition of offensive responding was dose-dependent (data not shown). These effects were specific to offensive responding, as fluoxetine did not affect motor activity tested inside a LAT maze (Fig. 2). These observations are consistent with our hypothesis that offensive responding in juveniles and in adults is controlled by a common neural circuitry.

Effects of stress on the development of aggression

Effects of stress in early puberty

The development of agonistic responding occurs during a period when juvenile hamsters become independent and consequently are likely to be exposed to a variety of adults, including territorial males. What are the consequences of repeated exposure to aggressive individuals? How would it alter the development of agonistic responding? These questions were addressed during experiments in which juvenile male hamsters were placed daily in the home cage of an aggressive adult for a limited period of time from a few days after weaning (postnatal day 28) until mid-puberty (postnatal day 42) (Delville et al., 1998; Wommack et al., 2003). In these experiments, control subjects were placed in empty cages to control for the stress of displacement and short-term relocation (Weinberg and Wong, 1986). Measurements of plasma cortisol showed elevated levels after the first day of stress in both groups (postnatal day 28, Fig. 3). However, after 2 weeks (postnatal day 42), only animals exposed to aggressive adults showed elevated cortisol levels. Apparently, control subjects had habituated to their manipulation, while experimental animals did not. Under these conditions, it was possible to test the effects of repeated stress by the aggressive adults.

In adult hamsters and rats, it has been reported that chronic stress results in altered body weight and lower testosterone levels (Huhman et al., 1991; Potegal et al., 1993; Blanchard et al., 1995; Meerlo et al., 1997). In our study, no such effect was observed either on body or on testes weight. This observation is important as it indicates that these animals grew normally and were likely capable of sexual activity. In adult hamsters, it has been reported that repeated exposure to aggressive males inhibits further aggressive behavior, even in the presence of smaller and weaker individuals (Potegal et al., 1993; Jasnow et al., 1999). The results obtained in our studies were significantly different. In an early study, we observed that male hamsters subjugated during puberty were less likely to attack animals of equal size and age, while more likely to attack smaller and younger individuals (Delville et al., 1998). In later studies, we looked at the development of agonistic respond-

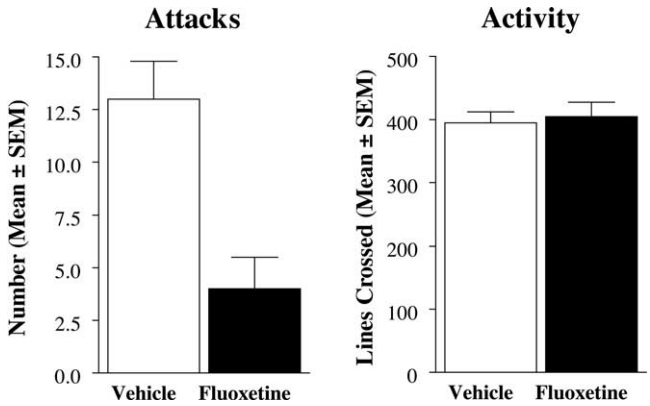

Fig. 2. Effects of acute treatment with fluoxetine (IP, 20 mg/kg dissolved in saline containing 25% DMSO) on the frequency of offensive responses (attacks) by juvenile hamsters (35 days old) toward smaller intruders for a period of 10 min and on the number of lines crossed in a LAT maze (activity) during a second 10-min period.

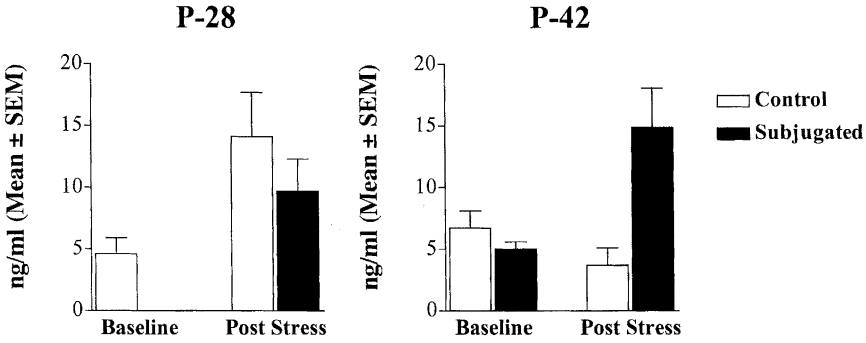

Fig. 3. Plasma cortisol levels measured from samples collected either before (baseline) or after a 20-min exposure to a stessor (poststress). The animals were exposed daily to their stressor from postnatal day 28 (P-28) to P-42. Stressors were either daily relocation to the home cage of an unknown aggressive adult and exposure to attacks and bites by this animal (subjugated) or relocation to an empty clean cage (control) for 20-min periods. Poststress samples were collected immediately after exposure to the stressor on P-28 and P-42 (the beginning and end of the stress training period).

ing in these subjugated hamsters. Interestingly, there was no effect of social stress on the frequency of attacks against smaller and younger individuals, at least during early puberty. However, after mid-puberty, subjugated animals performed twice as many attacks toward unknown intruders as their nonsubjugated controls (Wommack et al., 2003). We also looked at the development of attack types (Wommack et al., 2003). We observed that subjugated animals started performing adult-like attacks earlier during puberty, while performing a smaller proportion of play-fighting attacks. These differences were apparent after 1 week of subjugation, at the middle of the play-fighting period (P-35). The differences were clearly evident around mid-puberty (P-45) as hamsters switched from play-fighting to adult-like attacks.

These effects show that the development of agonistic responding is susceptible to the social environment of an individual. In addition, it is interesting to note that repeated social subjugation during early puberty does not inhibit gonadal development nor does it result in totally submissive individuals. It could be argued that these results make sense. Hamsters are territorial and solitary animals. It would be fairly common for juvenile hamsters to step into the territories of aggressive adults. Negative consequences on the growth and development of these juveniles would be detrimental for the survival of this species.

Effects of stress in late puberty

In the previous studies, hamsters were socially subjugated during early puberty (Delville et al., 1998; Wommack et al., 2003). The behavioral consequences are different from those observed in animals socially subjugated during adulthood (Potegal et al., 1993). Obviously, there must be a critical period separating these different effects of stress around peripubertal development. This period may be occurring during puberty or after puberty. In the following studies, animals were socially subjugated after mid-puberty, as they were still undergoing growth, but were well capable of reproductive behavior. These animals were exposed to aggressive adults for 15 days as for previous experiments. As in the previous experiments, control animals had been placed in an empty clean cage during the same period of time. Afterward, all animals were tested for offensive aggression in the presence of a smaller and younger intruder. In this study, subjugated animals were less likely to attack the intruders and more likely to retreat from them. Most control animals (6 of 8) attacked and bit their intruders within a minute, repeating this sequence several times during the 10-min test. None of the control animals retreated from their intruders. In contrast, none of the subjugated animals (0 of 11) attacked and bit their intruders within a minute. Instead, most of the subjugated animals (7 of 11) retreated from their intruders. However, these subjugated animals did not appear have a down-regulated hypothalamic–pituitary–gonadal axis, as they had tested weights similar to their controls. Our data suggest that stress responsiveness changes during mid-puberty. While stress exposure may enhance aggressive responding before mid-puberty, after mid-puberty it will result in a complete inhibition of aggressive responding. This suggestion is consistent with recent data showing differential endocrine and metabolic responses to a 3-day repeated restraint stress before and after mid-puberty in rats (Gomez et al., 2002). Together, these data support the possibility that stress responsiveness changes during puberty, regardless of the type of stressor.

Conclusions

Based of the data summarized above, we are proposing a new theory on the development of agonistic behavior in golden hamsters. This theory addresses the differences and similarities between play fighting by juveniles and aggression by adults. This theory involves changes in stress responsiveness across peripubertal development as well as the neural mechanisms underlying the expression of the offensive responding.

First, it is becoming clear that several factors differentiate play fighting by juveniles from aggression by adults. Besides differences in the patterns and frequency of attacks, there are other basic components that differ between these developmental periods. One such component is stress responsiveness, or more specifically, the consequences of defeat. During play fighting, hamsters often reverse roles as animals that previously attacked another become attacked themselves by the same individual (Pellis and Pellis, 1988a). However, this type of reversal is absent in adults. In adulthood, a single defeat will trigger a stress response preventing an individual from winning more fights (Jasnow et al., 1999). Our data suggest that this particular stress response becomes established after mid-puberty. This indicates that puberty is marked by a major change in the type of neural mechanism(s) activated as a consequence of defeat. Early on, defeat would have limited effects, at worst, resulting in alterations in the developmental patterns of offensive responding. After mid-puberty, defeat would result in severe behavioral consequences, marked by an inhibition of offensive responding. The nature of the differences between these developmental periods is still unclear. Future research will be conducted in our laboratory to address this question.

Second, regarding the development of offensive responses, it was previously suggested that play fighting and adult aggression are two separate categories of behavior in hamsters (Pellis and Pellis, 1988b). This suggestion was based of the differing patterns of attacks and bites between adults and juveniles. We are proposing that a single neural circuitry is responsible for the activation of offensive responsiveness throughout development. In hamsters, this circuitry is activated at the time juvenile hamsters become capable of coordinated movements. This network possibly involves serotonin neurons in the dorsal raphe nucleus and vasopressin neurons in the anterior hypothalamus. Early on, hamsters display agonistic behavior characterized by play fighting and flank marking. As animals undergo puberty, rising testosterone levels and the other changes associated with puberty reorganize this circuitry resulting in a transition from play-fighting to adult-like aggression. Afterward, agonistic behavior is characterized by adult-like aggression. The transition from one behavior to the other appears to be gradual, possibly involving a transitional period. Our theory about the development of agonistic behavior in hamsters is consistent with observations in primates. Low serotonin activity has been associated with aggressive behavior in juvenile monkeys as it is with adults (Higley, et al., 1992; Yodyingyuad et al., Keverne, 1985). Of course, additional evidence is required to confirm this hypothesis. Experiments are currently under way to further test this possibility. These experiments involve microinjections of receptor agonists and antagonists within the hypothalamus, as well as anatomical studies to uncover areas activated during play-fighting and adult-like aggression. However, the nature of the neural systems altered during puberty possibly by gonadal hormones is currently unclear. Future studies should focus on this developmental question. It must be noted that these conclusions are presently specific to hamsters. Play-fighting behavior differs between species. In rats, the development of agonistic behavior from play fighting to adult-like aggression includes three periods (Pellis and Pellis, 1990, 1997). The first period is characterized by rough play fighting. This early period is followed by a playful period involving gentle play. This second period is followed by a return to rough interactions during adult aggression. Hamsters do not have a period characterized by gentle play. Nevertheless, it is possible that the conclusions generated from hamsters may be applicable to rats. In this case, the first and third periods would share a common neural circuitry. The second period observed in rats would possibly involve a unique circuitry.

In addition, we also propose that the development of agonistic behavior is plastic, susceptible to a variety of environmental factors. We showed that exposure to stress during early puberty modifies the development of offensive responsiveness. Interestingly, this alteration appears to be independent from gonadal growth, suggesting that factors other that gonadal hormones participate in the development of offensive responding. In the present case, we predict that factors associated with stress responsiveness, such as cortisol, participate in this alteration in the development of offensive responding. Indeed, early studies have pointed to differences in the responsiveness of the hypothalamic–pituitary–adrenal axis to explain differences in aggressive behavior in rodents (Brain, 1972). The neural mechanisms underlying these behavioral changes are still unclear. Recent data are currently pointing to dopamine neurons inside the medial amygdala and bed nucleus of the stria terminalis (Wommack and Delville, 2002). However, the role of these neurons in the development of offensive responding is currently unclear.

The ecological significance of the effects of stress during development is unclear. Nevertheless, certain predictions can be proposed. The likelihood of being exposed to aggressive individuals during peripubertal development would depend on population density. Under conditions of high density of population, peripubescent hamsters would be very likely to be exposed to aggressive individuals. This exposure would cause most young hamsters to develop adult-like aggression and become more aggressive at earlier times than under low density of population. The result would be enhanced incidence of aggressive interactions between individuals and the establishment of a strict pyramidal hierarchy between individuals. Therefore, the effects of social stress during early puberty would be responsible for enhanced aggression as observed with increasing population densities in mice (Brown, 1953; Southwick, 1955; Greenberg, 1972).

Finally, all the data discussed in this review were focused on males. However, females, particularly female hamsters, are also capable of aggressive behavior, including offensive

aggression. Little is known about the neural substrate underlying offensive aggression in female hamsters. Recent studies performed in our laboratory have focused on the development of offensive responding in female hamsters (Taravosh-Lahn and Delville, unpublished data). Present data suggest that female aggression undergoes a similar progression from play fighting to adult aggression. Nevertheless, significant gender differences were uncovered in the development of offensive responsiveness in hamsters. It is likely that such differences are observable in other species as well.

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