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DIFFERENTIAL EFFECTS OF INTRASPECIFIC INTERACTIONS ON THE STRIATAL DOPAMINE SYSTEM IN SOCIAL AND NON-SOCIAL VOLES

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Abstract—We used *in vivo* microdialysis to examine the responses to intraspecific social interactions in the striatal dopamine systems of females of two vole species displaying vastly different social structures. Both highly social prairie voles and asocial meadow voles had similar increases in extracellular dopamine associated with mating. There was a species-specific effect of social condition on extracellular dihydroxyphenylacetic acid (DOPAC). Exposure to a conspecific male significantly decreased extracellular DOPAC in female prairie voles isolated for approximately 18 h during surgical recovery. Such decrease in DOPAC was not seen if females experienced continued isolation or if they were housed with a sibling during surgical recovery. No changes in extracellular DOPAC were seen in meadow voles after manipulations of social environment. Together, our data indicate that mating-associated dopamine release is independent from mating systems. However, species-specific patterns of extracellular DOPAC suggest that social isolation may be a more stressful stimulus for the social prairie vole than for the asocial meadow vole.

Key words: *Microtus*, striatum, stress, mating, isolation, DOPAC.

The dopamine (DA) system in the striatum has been linked to social behavior in humans. For example, Schneier et al. (2000) summarized a variety of evidence implicating DA function in social phobia in humans. Such linkage is supported by findings of lower D_2 binding potentials (Schneier et al., 2000) and lower DA reuptake site density (Tiihonen et al., 1997) in the striatum of patients suffering from social phobias. Studies using animal models also have implicated central DA in the control of some social behaviors as well as in the responses to social interactions. Mice deficient for catechol-O-methyltransferase or monoamine oxidase, enzymes involved in DA metabolism, were more aggressive in social interactions (Cases et al., 1995; Gogos et al., 1998). Social isolation of both young and adult rats increased striatal DA activity (Blanc et al., 1980; Kehoe et al., 1996; Rilke et al., 1995) and exacerbated decreases in DA transporter binding in the striatum associated with social defeat (Isovich et al., 2001). Social factors also can affect responses to non-social stressors. In rats, changes in striatal DA associated with non-social stressors were reduced if the animals were housed with a familiar conspecific during the stress (Ge et al., 1997).

The Microtine rodents (voles) provide an ideal model for the comparative study of central responses to social interactions. The various vole species are closely related taxonomically, and yet display fundamentally different social systems. Meadow voles (*Microtus pennsylvanicus*) are promiscuous, do not form pair bonds, and typically only the female provides parental care (Dewsbury, 1987). In contrast, prairie voles (*Microtus ochrogaster*) form long-term monogamous pair bonds, share a common nest, vigorously defend their mate from other conspecifics, and provide bi-parental care (Dewsbury, 1987; Getz et al., 1981). Such drastic differences in complex suites of behavior suggest important differences in the central processing of socially relevant information.

Recently, central DA systems have been implicated in social behavior in voles. Female prairie voles that mate repeatedly over several hours reliably form pair bonds with the male partner and central administration of a DA antagonist blocks this effect (Wang et al., 1999). Conversely, unmated female prairie voles rarely form pair bonds unless housed with a male for several days. Administration of a DA agonist can induce pair bonds in a few hours in the absence of mating (Wang et al., 1999). Interestingly, stress, and responses associated with stress, can also affect pair bonding in voles. Elevated corticosterone or the stress associated with forced swimming both can inhibit pair-bond formation in female prairie voles (DeVries et al., 1995, 1996). As both mating and stress significantly affect the DA system in the striatum (Abercrombie et al., 1989; Becker et al., 2001; Farooqui et al., 1996; Jenkins and Becker, 2001; Mermelstein and Becker, 1995; Pfaus et al., 1995), it is possible that species differences in social structure may be related to species-specific striatal DA responses to social interaction. Here we apply a comparative approach to examine the effects of social interactions on the DA release in the striatum of social and non-social voles. In addition, since changes in DA metabolites may provide important information about changes in the DA system (Abercrombie et al., 1989; reviewed by Westerink, 1995), we also measured dihydroxyphenylacetic acid (DOPAC) and homovanillic acid (HVA).

EXPERIMENTAL PROCEDURES

Subjects were female prairie and meadow voles from captive breeding colonies. After weaning around 21 days of age, pups were kept in same-sex sibling groups (two to three/cage) until

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Abbreviations: DA, dopamine; DOPAC, dihydroxyphenylacetic acid; EB, estradiol benzoate; EDTA, ethylenediaminetetraacetic acid; HVA, homovanillic acid; NAcc, nucleus accumbens.

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used in experiments. Animals were housed (plastic shoebox-style cages, 29×19×13 cm) under a 14-h/10-h light/dark cycle with lights on at 0700 h and temperature was maintained at approximately 21 °C. Food and water were provided *ad libitum*. Subjects were about 70 days of age at the time of the experiments. All experiments were performed during the light phase. Experimental procedures were approved by the Institutional Animal Care and Use Committee at Florida State University. The minimum number of animals consistent with the necessary statistical analyses were used.

Probe implantation and dialysate sampling and analysis

Concentric-style microdialysis probes were constructed as previously described (Sved and Curtis, 1993) except the membrane had a molecular weight cutoff of 20 kd and the active area was 2 mm. Immediately prior to implantation all probes were tested at room temperature for DA recovery in a solution containing 20 pg/μl of DA in dialysis fluid (144-mM NaCl, 2.8-mM KCl, 1.2-mM $CaCl_2$, 0.9-mM $MgCl_2$; Sved and Curtis, 1993). Sexually naive females were used in all experiments. Since mating effects were to be examined in some animals, all females were injected with estradiol benzoate (EB, 0.1 μg in 0.1 ml sesame oil) once daily for 3 days. On the third day of EB treatment, females were anesthetized (sodium pentabarbitol, 1 mg/10-g bodyweight) and probes directed at the striatum were implanted (stereotaxic coordinates: flat skull, anterior 0.9 mm and lateral 1.9 mm from bregma, ventral 5.3 mm from skull surface). Probes were perfused continuously at 1.0 μl/min with dialysis fluid. After overnight recovery, three 30-min baseline samples were collected prior to altering social conditions. Treatment samples then were collected at 30-min intervals for 6 h. Samples were collected manually into vials containing 5 μl of 0.1-N perchloric acid. For those females that remained isolated, a total of fifteen 30-min samples were collected with the first three samples treated as baseline samples; the remaining 12 samples corresponded to the treatment period for other females. For all animals, after the last test sample was collected, the dialysis fluid was replaced with one containing a higher concentration (60 mM) of potassium (high K^+, potassium replaced sodium). At least 90 min after the changeover, a final sample was collected to assess the ability to detect changes in extracellular DA. At the end of the experiment, animals were over-anesthetized and the dialysis fluid was replaced with dye (1% fast green). Five minutes after the dye reached the active area of the probe, animals were killed, and the brains were removed, sectioned at 40 μm, and examined histologically to verify probe placements. Several animals were excluded from analysis due to misplaced probes.

Dialysate content of DA, DOPAC, and HVA was assessed using high performance liquid chromatography. Peak separation was achieved using an Alliance Separations Module (Waters, Inc., Milford, MA, USA), a microdialysis MD-150 analytical column (ESA, Inc., Chelmsford, MA, USA) and mobile phase (0.7 ml/min) consisting of 75-mM sodium dihydrogen phosphate monohydrate (EM Science, Washington, PA, USA), 1.7-mM 1-octanesulfonic acid sodium salt (Sigma, St. Louis, MO, USA), 0.01% triethylamine (Aldrich), 25-μM EDTA (Fisher, Pittsburgh, PA, USA), 10% acetonitrile (EM Science); pH adjusted to 3.85 with 85% phosphoric acid (Fisher). Electrochemical detection of analytes was performed using an ESA Coulochem detector. Samples were first oxidized at 250 mV then reduced at −250 mV, and peak areas were quantified from the reduced sample.

Group assignments and behavioral assessment

For each species, females were initially assigned to one of two groups. Females (n=6/species) in the first group remained isolated during recovery from surgery and throughout the sampling period to serve as baseline controls. Females from the latter groups were exposed to male conspecifics for 6 h. Behavior was videotaped throughout the sampling period for analysis of mating behavior, social interactions, and locomotor activity. Treatment with EB induces sexual receptivity in a majority of female voles; however, despite being exposed to a sexually receptive female, some male voles will not mate (Winslow et al., 1993). Therefore these animals were further divided in two groups: females exposed to males and that mated (n=5/species) and male-exposed females that did not mate (n=19 for prairie voles, n=8 for meadow voles). For each paired female, the amount of time spent in close contact with the conspecific was quantified as an index of affiliative behavior, and the number of times the subject crossed the midline of the cage was used as an index of locomotor activity. Initial analysis suggested that isolation during surgical recovery might have been stressful for female prairie voles; therefore, two additional groups of prairie vole females (n=6/group) were added to assess the affects of the presence of a sibling during surgical recovery. In these groups, both the subject and its sibling were anesthetized and allowed to awaken together. Both animals then remained together during the subject's recovery period after surgery. For both groups, after baseline samples were collected, the sibling was removed from the test cage, and subject either then had the sibling replaced by a male or remained alone during the sampling period. As with the earlier groups, videotapes were made for subsequent behavioral analysis.

Data analysis

All statistical analyses were made using a computerized statistical software package (Statistica). Activity levels and social contact were assessed using two-way repeated measures ANOVA with species and treatment as main factors and time as the repeated measure. Comparisons of basal sample concentrations of DA, DOPAC, and HVA were made using two-way ANOVA on mean analyte amounts after correction for probe recovery with species and treatment used as factors. It must be noted that, although sample results were corrected for probe recovery, these results still represent an estimate of extra-cellular concentrations of analytes. A no-net-flux analysis would be necessary to establish more exact measures of the absolute amounts of analytes in the extracellular environment.

DA, DOPAC, and HVA were expressed as percent of the mean within-animal baseline amount in all other comparisons. One-way repeated measures ANOVA was used to assess group differences in DA, DOPAC, and HVA within each species, with treatment as the main factor and time as the repeated measure. It was necessary to estimate values for several missing samples to use the repeated measures analysis. In those cases, the mean for all samples for the appropriate time period was first calculated. Median interpolation was then used to estimate the missing value. The average of these two estimates was then used to replace the missing value. Comparisons of mating effects on extracellular DA were made using two-way ANOVA using species and treatment as factors. For these comparisons, the values for the first sample during which each pair of voles mated were compared with the mean of their respective baseline samples. Since the exact timing of mating differed between pairs and the magnitude of the DA response at any given time point simply reflected the number of females that mated during that particular time point, mated females did not constitute a valid group for the time-course analysis. Therefore the DA data for mated females were not compared with those of unmated and unpaired females. In all cases where a significant main effect or interaction was detected, Student-Newman-Keuls post-hoc analyses were performed. Statistical significance was assessed at a P value at 0.05.

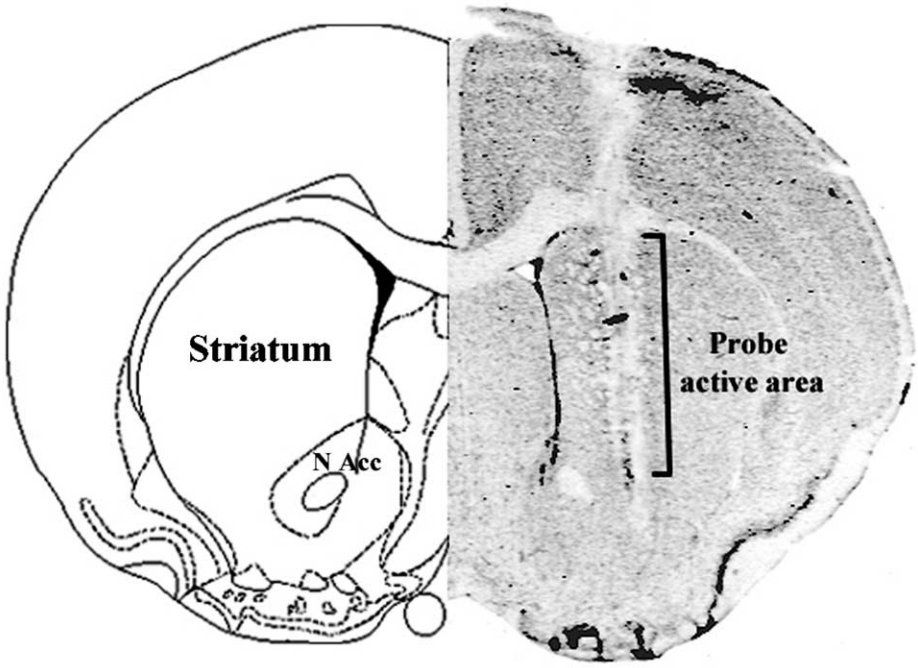

Fig. 1. The active area of the dialysis probe (box) was placed in the dorsal striatum. The right side shows a representative coronal hemi-section containing the probe track. The left side shows the analogous diagram (scale reduced) from Paxinos and Watson (1998).

RESULTS

Probe parameters

Probe recovery for DA was 8.3±0.6%. Probes were vertically oriented with the active area lateral to the anterior commissure and extending from immediately ventral to the corpus callosum to about the level of the anterior commissure (Fig. 1). Although the active area of the probe was entirely within the striatum, the sealed portion of the probe tip typically extended into nucleus accumbens (NAcc). As such it is possible that leakage along the probe track from NAcc may have occurred. Samples collected after switching to the high K^+ dialysis fluid averaged approximately 500% of baseline DA values.

Behavior

For both prairie and meadow vole females that recovered alone, the first several sample periods after male introduction were characterized by increased activity (Fig. 2a, e). There was no main effect of species ($P=0.84$) and no interaction between species and social condition ($P=0.79$). There was a main effect of social condition ($F_{2,28}=4.95$, $P<0.05$), with females of both species exhibiting more activity when exposed to males than when left in isolation. By 2.5 h after male introduction, activity levels for females of both species had returned to baseline levels. The prairie vole females that recovered from surgery in the presence of their sibling (Fig. 2c) displayed an activity pattern similar to those displayed by isolated females after the male was introduced. Activity levels increased after the change in social condition regardless of whether the sibling was replaced with a male or if the test animal was left isolated. Again, activity levels declined to baseline levels within a few samples.

Among females that recovered from surgery in isolation, the amount of time spent in social contact differed between species ($F_{1,11}=106.1$, $P<0.001$) after the second sample post-male (Fig. 2b, f). For prairie voles, the amount of time spent in close contact with the male was opposite that of the activity pattern: as the activity level decreased, the amount of time spent in contact increased. By the third sample period after male introduction, females were spending one half to two thirds of their time in close contact with the male. Overall, female prairie voles spent about 60% of their time in contact, and there was no difference between mated (63.4± 7.7%) and unmated females (59.3±3.8%). Meadow voles, in contrast, spent little time in close contact. Ten of 13 meadow vole females spent no time in contact with the male, and among those that exhibited any social contact, the amount was minimal. As with the prairie voles, there was no difference between mated (3.8± 3.8%) and unmated females (4.8±3.1%). Female prairie voles that recovered with their sibling maintained contact with the sibling throughout the baseline period (Fig. 2d). For these females the percentage of time spent in social contact was similar (approximately 60%) to that spent by previously isolated females after they had settled down with the male. Those females that had the sibling replaced with the male displayed a transient decrease in contact with a conspecific that coincided with the increase in activity when the sibling was replaced with the male.

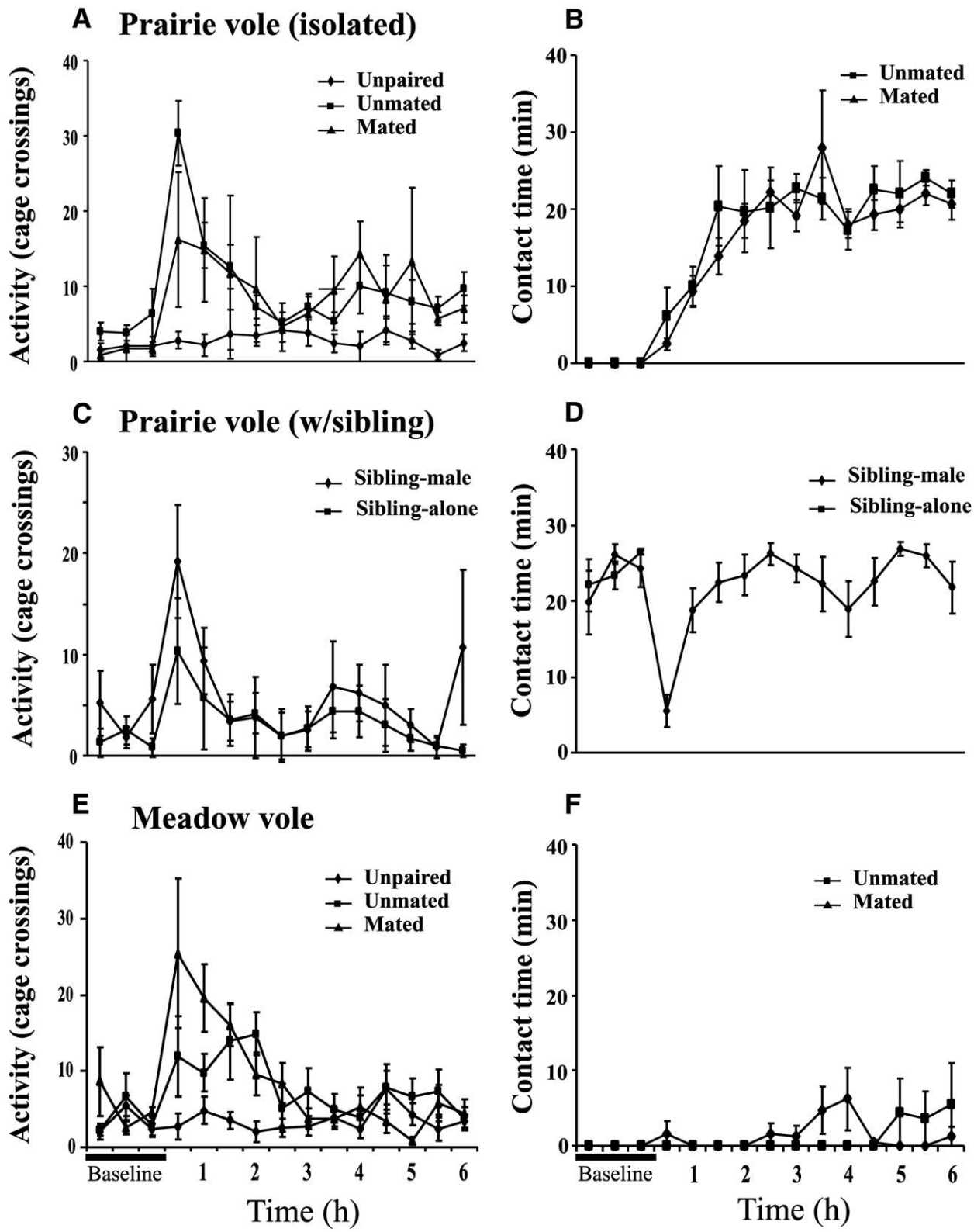

Fig. 2. Changes in social condition produced changes in locomotor activity and social contact in both species. Panels A–D show data from prairie voles; panels E and F are for meadow voles. A shows locomotor activity and B shows contact time with a male for female prairie voles that recovered from surgery in isolation. C and D show activity and male contact for prairie voles that recovered from surgery with a sibling. E and F show activity and contact for meadow voles. In each panel the first three samples represent baseline samples. Social conditions were altered following the third baseline sample.

A

	Baseline DA (pg/30ul)	
	Prairie vole	Meadow vole
Unpaired	21.4±2.3	24.7±2.8
Unmated	20.6±2.8	20.0±1.9
Mated	24.6±2.0	21.2±2.6
Sibling/male	26.9±3.8	———
Sibling/alone	22.6±2.7	———

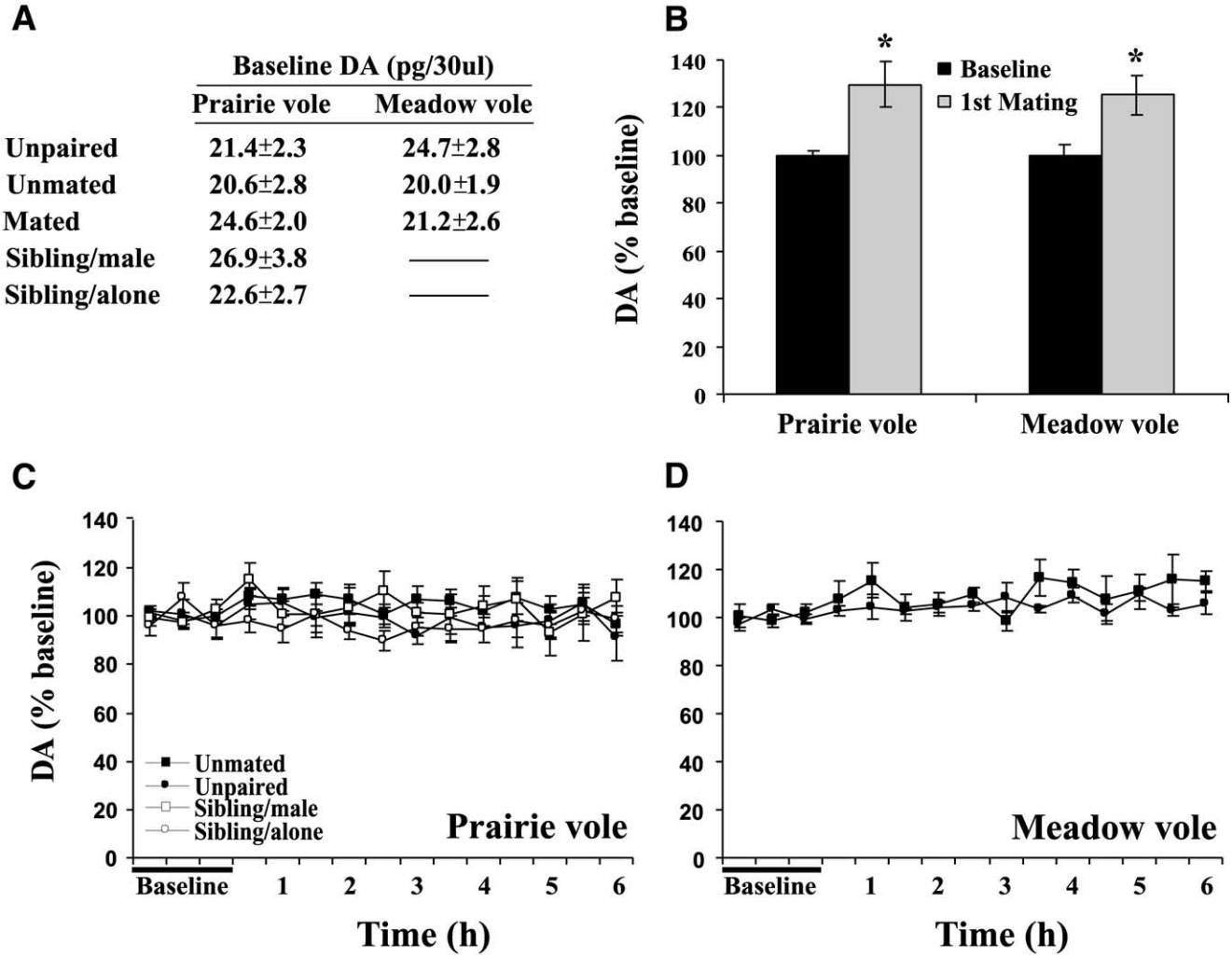

Fig. 3. Mating, but not other social interaction, was associated with a change in extracellular DA in the striatum of both prairie and meadow vole females. (A) Baseline DA concentrations. Data for the sibling/male and sibling/alone groups were collected only for prairie voles. (B) Change in extracellular striatal DA associated with mating; comparison is made between mean baseline value and the first sample during which each pair mated (*, significantly greater than baseline). Panels C and D show extracellular DA responses after varying social conditions. Social conditions were altered following the third baseline sample.

DA

There were no treatment effects ($P=0.98$) and no species differences ($P=0.51$) for basal DA levels (Fig. 3a). Significant increases (approximately 25%) in extracellular DA levels in the striatum were associated with mating for both prairie and meadow vole females ($F_{1,12}=24.9$, $P<0.001$; Fig. 3b). Non-sexual social contact with the male did not affect extracellular DA in either species (Fig. 3c, d). There were no apparent effects associated with isolation following surgery.

DOPAC

Among previously isolated females there was a significant species effect for basal DOPAC ($F_{1,2}=6.12$, $P<0.02$), but no treatment ($P=0.68$) or interaction ($P=0.73$) effects. Basal levels of DOPAC were higher for prairie voles than for meadow voles in all treatment conditions (Fig. 4a). Female prairie voles that recovered with a sibling had basal DOPAC levels that were significantly lower that those of isolated females ($F_{4,56}=2.83$, $P<0.05$) and that were similar to those of meadow voles (Fig. 4a). There were no changes in extracellular DOPAC associated with mating in either species (Fig. 4b). Social interactions produced species-specific changes in extracellular DOPAC levels. Among prairie voles, DOPAC levels declined across time in previously isolated females exposed to males, whether mated or unmated (Fig. 4c). This decline was not seen in females that remained unpaired throughout or in females that were housed with their sibling during recovery from surgery. By the end of the fourth hour of exposure to a male, DOPAC levels had fallen to 70–80% of baseline and these values were significantly lower than both within-group baseline levels (all $P<0.05$), and the cor-

A

	Baseline DOPAC (pg/30ul)	
	Prairie vole	Meadow vole
Unpaired	3207±463[a]	2047±275*
Unmated	3206±272[a]	2497±287*
Mated	3033±377[a]	2112±502*
Sibling/male	2272±170[b]	———
Sibling/alone	2026±134[b]	———

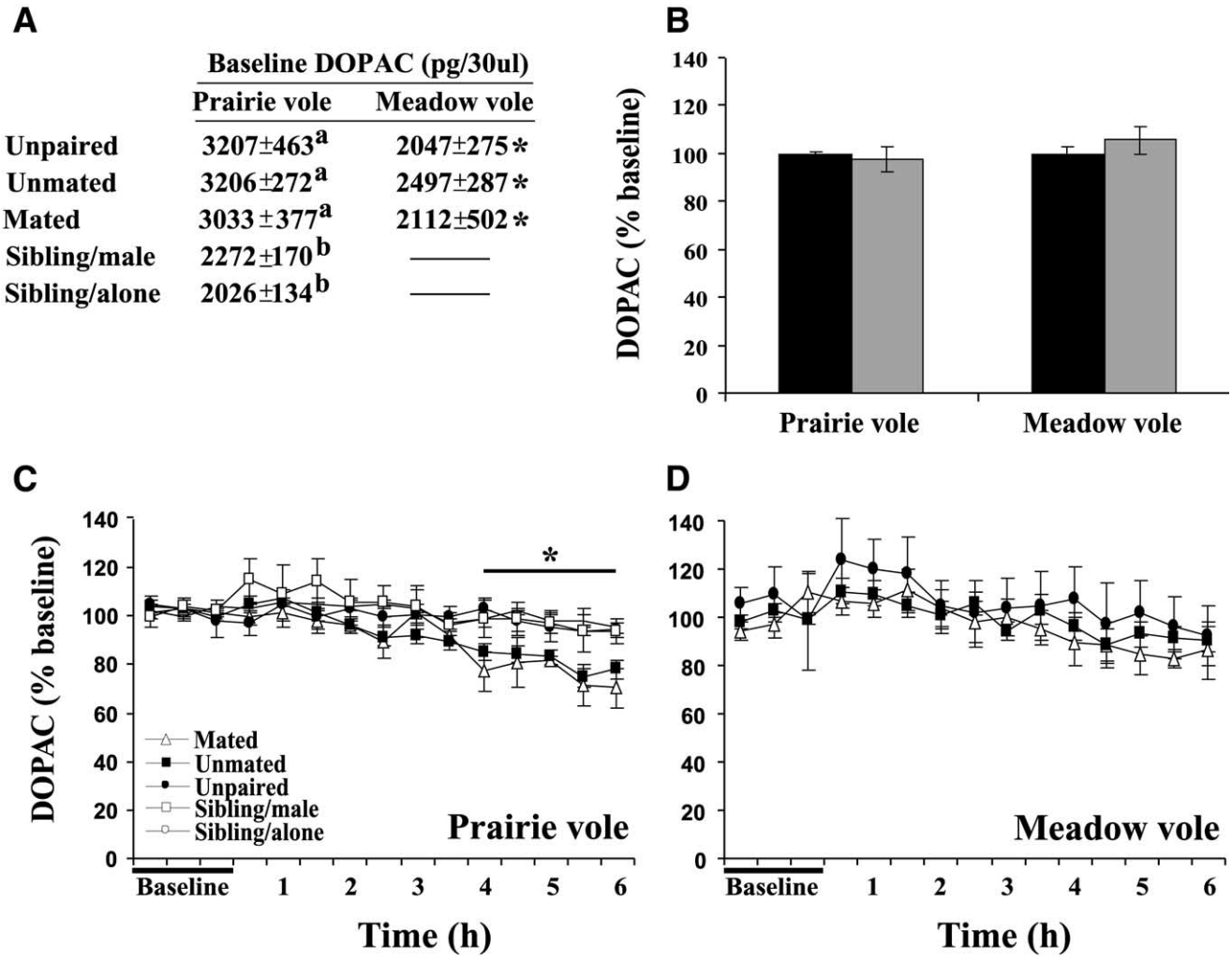

Fig. 4. Isolation was associated with elevated extracellular DOPAC in the striatum of prairie vole, but not meadow vole, females. (A) Baseline striatal DOPAC for female prairie and meadow voles. Data for the sibling/male and sibling/alone groups were collected only for prairie voles. The results of two separate comparisons are presented. First, isolated prairie voles had higher baseline DOPAC than did those housed with a sibling after surgery (groups with shared letters are not significantly different); second, when isolated during recovery from surgery, prairie voles had higher baseline DOPAC than did similarly treated meadow voles (*, significantly lower than corresponding value for prairie vole). (B) DOPAC comparison between baseline levels and those for the first sample during which each pair mated. Panels C and D show extracellular DOPAC responses after varying social conditions (*, samples for previously isolated females exposed to males had lower DOPAC levels than corresponding baseline samples). Social conditions were altered following the third baseline sample.

responding samples for baseline females (all $P<0.05$). Meadow voles displayed no significant changes in extracellular DOPAC within groups across time when compared with baseline values ($P=0.70$; Fig. 4d). Further, in comparisons between the mated and unmated groups, and the unpaired group, meadow vole females did not differ from unpaired females at any time point after exposure to males (Fig. 4d).

HVA

There were no treatment ($P=0.40$) or species ($P=0.32$) differences in basal HVA levels (Fig. 5a). There were no mating associated changes in extracellular HVA (Fig. 5b). HVA was not affected by changes in social condition in either species (Fig. 5c, d).

DISCUSSION

In the present study we compared effects of social interactions on the striatal DA systems of highly social female prairie voles and non-social female meadow voles. In both species mating was associated with increases in extracellular DA that appeared to be independent from locomotor activity. Isolation and subsequent exposure to a male produced species-specific patterns of change in extracellular DOPAC but not in extracellular DA. HVA was not affected by any of the social manipulations in either species.

Recently it has become apparent that central DA systems are important in the regulation of social behavior in voles (Gingrich et al., 2000; Wang et al., 1999; Aragona et

A

	Baseline HVA (pg/30ul)	
	Prairie vole	Meadow vole
Unpaired	5047±774	4835±1164
Unmated	4790±539	3917±760
Mated	3361±809	3160±228
Sibling/male	3730±358	———
Sibling/alone	4135±182	———

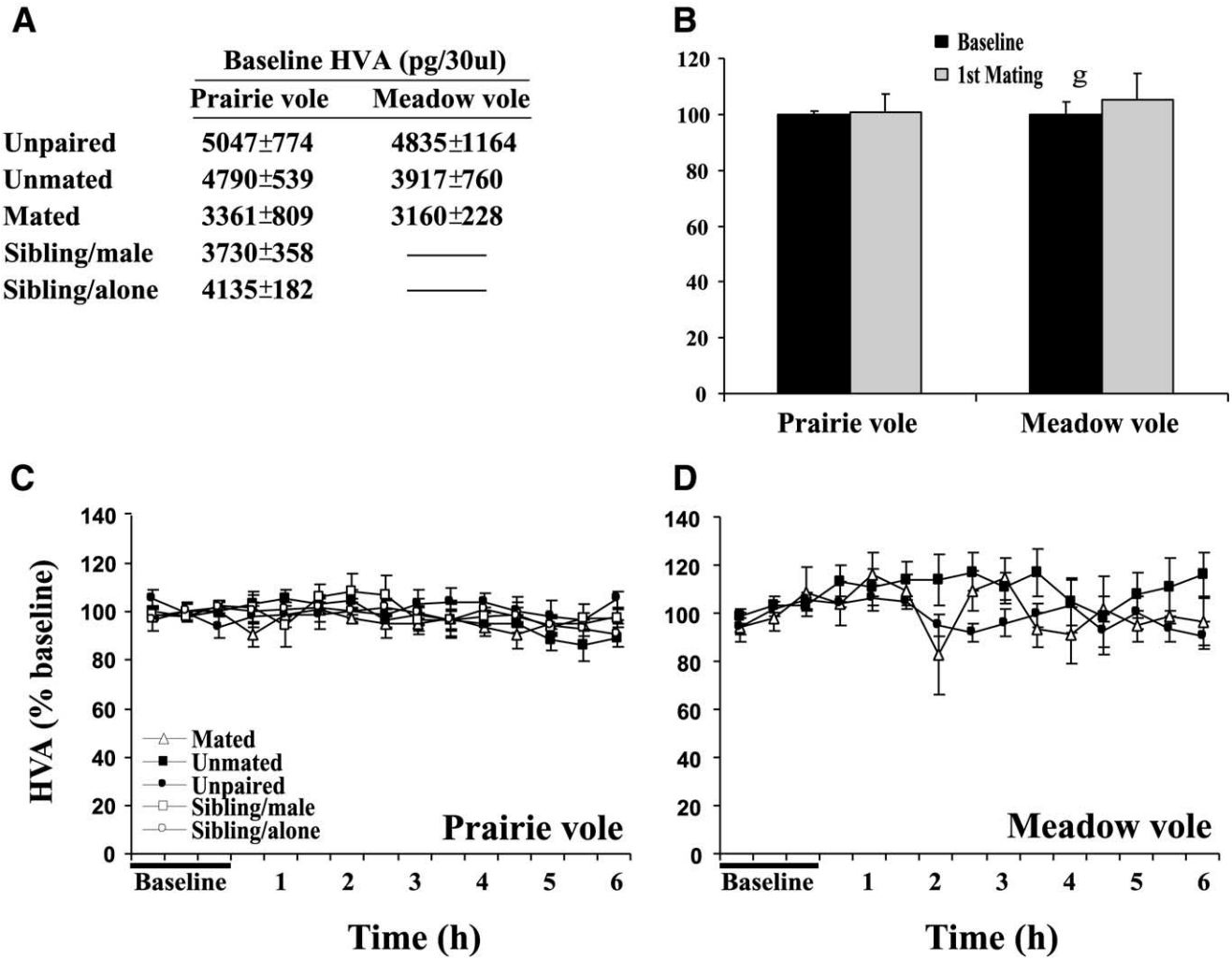

Fig. 5. Social conditions had no effect on extracellular HVA in either species. (A) Baseline striatal HVA for female prairie and meadow voles. Data for the sibling/male and sibling/alone groups were collected only for prairie voles. (B) HVA comparison between baseline levels and those for the first sample during which each pair mated. Panels C and D show extracellular HVA responses after varying social conditions. Social conditions were altered following the third baseline sample.

al., 2002). Vole species display drastically different social systems, exemplified by differences in the formation of social attachments; mating stimulates the formation of pair-bonds in female prairie voles, but not in meadow voles. One possible explanation for the species differences in social structure may involve differences in central DA responses to social contact. It is known that sexual contact increases DA release in the striatum (Becker et al., 2001; Mermelstein and Becker, 1995; Pfaus et al., 1995). It is possible that differences in the striatal DA systems in voles may contribute to the species-specific social behaviors, in this example, pair-bonding. The striatum has been implicated in associative learning (Han et al., 1997), a process likely to be important in pair-bond formation, may play a role in processing the reward value of sexual stimuli (Becker et al., 2001), and may be involved in the formation of conditioned place preferences (Baker et al., 1998). To date, however, the effects of social interaction on the DA system in the vole striatum have not been assessed.

We found no species differences in either basal levels of extracellular DA or in the magnitude of mating-associated increases in DA release. It must be noted that the mated and unmated females were self-selecting and, as such, we cannot be sure whether the change in extracellular DA was the cause of, or an effect of, mating. However, in females of both vole species, the striatal DA release associated with mating was of similar magnitude to that found in rat (Mermelstein and Becker, 1995; Pfaus et al., 1995), suggesting that the changes we observed were the result of copulation.

Pfaus et al. (1995) suggested that the increase in striatal DA in female rats during copulation resulted from locomotor activity associated with mating. In contrast Becker et al. (2001) found mating-induced increases in striatal DA that were independent from locomotion. In the present study there were no significant differences in extracellular DA between unmated and unpaired females at any time point, despite very different patterns of locomo-

tion. This result suggests that the increased DA seen in mated female voles was not simply the result of increased locomotion associated with mating.

The lack of species differences in striatal DA responses suggests that the species-specific mating systems are not the result of differences in mating-associated DA release. However, it is still possible that there are species differences in the striatal DA systems but they may be receptor-mediated rather than release-mediated. Female prairie voles can form pair bonds in the absence of mating, but only after prolonged, direct physical contact with the male (Carter et al., 1980, 1987; Williams et al., 1992) during which they experience increased levels of circulating estrogen. In rats, elevated estrogen can alter the density of post-synaptic DA receptors in the striatum (Fernandez-Ruiz et al., 1989; Hruska and Pitman, 1982; Hruska, 1986) and this effect occurs in the same timeframe in which estrogen levels rise in female voles. Further, it has been suggested that the effects of elevated estrogen are specific to D_2 receptors (Fernandez-Ruiz et al., 1989; Hruska, 1986; Hruska and Silbergeld, 1980; Roy et al., 1990), the DA receptor sub-type implicated in pair-bond formation in prairie voles (Wang et al., 1999). If there are species differences in the effects of changes in circulating estrogen on the striatal DA system, the striatum may still contribute to species differences in social structure.

Meadow voles displayed no changes in extracellular DOPAC after exposure to the male, either relative to the within-group baseline or to females that remained in isolation. In the prairie voles, however, previously isolated females exposed to males, but not females that remained isolated, displayed a consistent decrease in extracellular DOPAC in the striatum. This effect was significant relative both to within-group baselines and to females that remained isolated. It is important to note that females in groups that recovered in isolation had baseline DOPAC levels that were elevated relative to females who recovered with a sibling. These latter females did not show the decline in DOPAC.

The changes in DOPAC levels may reflect species-specific patterns of social contact. After an initial period of increased locomotion associated with the introduction of the male, females of both species returned to baseline activity levels. However, the subsequent behavior of the two species relative to conspecifics differed. The prairie voles spent the majority of their time in close contact, resting together in one corner of the cage. In contrast, meadow voles spent little if any time in close contact, and in fact, appeared to stay as far from the conspecific as possible. These behavioral responses lend further support to the suggestion that isolation is stressful for social prairie voles. Stressors that do not elicit locomotor behavior typically do not produce large increases in extracellular levels of DOPAC in the striatum (Abercrombie et al., 1989; Bertolucci-D'Angio et al., 1990a,b). However, Bertolucci-D'Angio et al. (1990b) suggested that DA systems could be differentially activated under different environmental situations. Since the striatal response to stress differs even among rats of different strains (Lindley et al., 1999), the possibility of species-specific responses to stress should be considered (Blanchard et al., 2001).

Prairie voles are highly social animals, and in this species social isolation significantly elevates serum corticosterone and decreases bodyweight (Kim and Kirkpatrick, 1996) and is sufficient to decrease neurogenesis in adult females (Fowler et al., 2002). DOPAC in the striatum and elsewhere has been shown to increase in response to stress, possibly reflecting increased DA synthesis (Abercrombie et al., 1989; Castro et al., 1996). If DOPAC levels in the striatum similarly reflect stress in voles, one explanation for the decline in DOPAC across the time of the experiment is that the addition of the male relieved isolation stress on the part of the female and stress-induced levels of DOPAC began to drop. The fact that females lacking exposure to a conspecific did not display the decrease in DOPAC and observations that the introduction of a male reduced serum corticosterone in previously isolated female prairie voles (DeVries et al., 1995) also are consistent with an interpretation that the introduction of a conspecific relieves isolation stress. In rats, changes in striatal DA associated with non-social stressors are reduced if the animals are housed with a familiar conspecific during the stress (Ge et al., 1997). Thus, the lower baseline levels and lack of subsequent decline in DOPAC in female prairie voles that recovered with their sibling may reflect a protective effect of housing with a conspecific during recovery from surgery, a non-social stressor. These results suggest that voles, in addition to providing an excellent model for the study of social attachment, may be useful models for the study of psychic stress.

In summary, we have shown that a mating-associated increase in striatal DA occurs in voles as in rats and that the increase is independent from changes in locomotion. The lack of differences between social and non-social voles suggests that species-specific mating systems are not the result of differences in mating-associated DA release in the striatum. We have also shown that contact with conspecifics produces differential responses in the striatal DA system. The species-specific changes in DOPAC provide further evidence that isolation may be stressful for the highly social prairie vole.

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