Further Observations on the Role of Nitric Oxide in the Feline Lateral Geniculate Nucleus

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Abstract

We have examined the responses of a population of 77 cells in the dorsal lateral geniculate nucleus (dLGN) of the anesthetized, paralyzed cat. Here the synthetic enzyme for the production of nitric oxide, nitric oxide synthase, is found only in the presynaptic terminals of the cholinergic input from the brainstem. In our hands, iontophoretic application of inhibitors of this enzyme resulted in a significant decrease in visual responses and decreased responses to exogenous application of NMDA, effects which were reversed by coapplication of the natural substrate for nitric oxide synthase, L-arginine, but not the biologically inactive isomer, D-arginine, nitroprusside and S-nitroso-N-acetylcysteamine (SNAP). Nitric oxide donors, not L-arginine, were able to increase markedly both spontaneous activity and the responsiveness to NMDA application. Furthermore, SNAP application facilitated visual responses. Responses of cells in animals without retinal, cortical and parabrachial input to the LGN suggest post-synaptic site of action of nitric oxide. This modulation of the gain of visual signals transmitted to the cortex suggests a completely novel pathway for nitric oxide regulation of function, as yet described only in primary sensory thalami of the mammalian central nervous system.

Introduction

The dorsal lateral geniculate nucleus (dLGN) or the cat is a major target of input from the retina, and in recent years there has been a large amount of work directed towards isolating the functional significance of the complex synaptic physiology of this nucleus (Murphy and Silipo, 1987; Fonkel and Eyssel 1992; Silipo et al., 1993; Lo and Sherman, 1994; Silipo et al., 1994). Besides the visually specific pathways involving this nucleus, there exist a number of modulatory pathways considered to influence the activity of dLGN cells more globally, thus having a putative role in sleep/wake and arousal states (for reviews see Kang, 1977; Steriade and Llinas, 1986; McCormick, 1992). One such pathway is the cholinergic pathway from the parabrachial nucleus of the brainstem, activity of which releases acetylcholine (ACh) within the dLGN. ACh is known to excite dLGN relay cells directly (Silipo et al., 1983; Eyssel et al., 1986; McCormick and Pape, 1988). Intriguingly, recent evidence has shown that within the feline dLGN there is a unique distribution of nitric oxide synthase (NOS), the enzyme responsible for the production of nitric oxide. NOS is found exclusively within the ACh-containing fields residing in the parabrachium (Bickford et al., 1993). Since nitric oxide is now considered to be a widely spread CNS neuromodulatory substance, which is also a highly diffusible gaseous compound (for reviews see Ganthwaite, 1991; Moncada et al., 1991; Snyder and Breidt, 1991; Schuman and Madison, 1994), this represents a novel colocalization of neurotransmitter substances. Nitric oxide is produced from L-arginine by the action of NOS, and has traditionally been viewed as a retrograde messenger, diffusing from postsynaptic structures to act remotely, for example on pre-synaptic terminals (Ganthwaite et al., 1988; Ganthwaite, 1991; O'Donnell et al., 1991; Snyder and Breidt, 1991). It has been suggested that nitric oxide is involved in glutamatergic neurotransmission, by increasing synaptic release of the excitant (Dawson et al., 1991, 1993). Other evidence, however, has favoured the view that nitric oxide may act to reduce NMDA-mediated neuroexcitotoxicity, by an action directly on NMDA receptor configuration (Lo et al., 1992; Mauzou et al., 1992; Lipton et al., 1992).

We have recently presented preliminary evidence using iontophoretic aplication of putative inhibitors of NOS, suggesting that, within the cat dLGN, nitric oxide acts to enhance visual responses, specifically and selectively enhancing NMDA-mediated excitation (Codierto et al., 1994a,b). Unlike the interaction of coagonizators such as ACh and excitatory intestinal peptid in the autonomic nervous system, where the colocalized pepitide extends the effective range of activity of the cholinergic neurotransmitter (Ludwig et al., 1980), in the dLGN nitric oxide seems to facilitate NMDA-mediated excitation selectively, without an apparent action on ACh-mediated activity (Codierto et al., 1994b). Activation of NMDA receptors is known to provide a major component of the retinal input to dLGN.

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(Kemp and Sitio, 1982; Hartveit and Heggelund, 1990; Heggeland and Hartveit, 1990; Schiffran et al., 1990; Sitio et al., 1990a; Kwon et al., 1992). By these means nitric oxide may potentially modulate visually driven activity. In this paper we examine further this effect of blockade of NOS in the cat dlGN, and examine the effect of application of nitric oxide donors.

Materials and methods

Animal preparation

Experiments were carried out on adult cats in the weight range 1.8–3.0 kg. Animals were anaesthetized with halothane in nitrous oxide (70%) and oxygen (30%) the concentration of halothane was 5% for induction, 1.5–2% for surgery and 0.1–0.5% for maintenance. To prevent eye movements, animals were paralysed with gallamine triethiodide (loading dose of 40 mg, maintenance 10 mg/kg/h i.v. infusion). End-tidal CO₂ levels, EEG waveform, interoncalcular voltage and the frequency of spikes in the EEG were monitored continuously throughout the experiments.

The rate and depth of artificial respiration were adjusted to maintain end-tidal CO₂ at 3.8–4.2%; the level of halothane was chosen to achieve a state of light anaesthesia. Once a stable state was reached, any variation in the monitored parameters commensurate with a change in the depth of anaesthesia was compensated for by alterations in the level of halothane. Woolen margins were treated with lignocaine hydrochloride with adrenaline solution subcutaneously. Ear bars were coated with lignocaine gel. The eyes were treated with atropine methasulfate and phenylephrine hydrochloride, protected with zero power contact lenses and brought to a focus on a semi-epikeratonic tangent screen 57 cm distant. Visual stimuli were viewed monocularly through 3 mm artificial pupils.

Recording and iontophoretic application of drugs

Seven-barrelled microjector were used for iontophoresis and press

suction ejection of drugs and single-unit extracellular recording in the A lamina of the cat dlGN. Drug barrels contained a selection of the following solutions: NaCl (0 M for recording), l-arginine (l-Arg, 10 mM, pH 6.0), arginine (Arg, 10 mM, pH 7.0), l-lysine (Lys, 10 mM, pH 7.0), l-phenylalanine (Phe, 10 mM, pH 7.0), sodium nitroprusside (applied by pressure ejection, 10 mM, 6,7-dimethylxanxyl-x, x-penicillamine (SNAP) applied by pressure ejection, 10 mM), NMDA (10 mM, pH 8.0), kynurenic acid (KABA, 0.5 M, pH 7.2) or pontamine sky blue (2% w/v, in 8.5 M sodium acetate solution, for histological reconstruction). Pipette tips were bent back to diameters ranging from 3 to 10 μm, and each drug barrel was subject to a current of 5–25 nA of appropriate polarity.

Visual stimulation and experimental design

Cells were classified by a battery of tests into X and Y groups of ON and OFF subtypes. Particular emphasis was placed on the linearity of spatial summation in the responses to sinusoidal gratings of the appropriate spatial frequency. Sinusoidally phase-reversed gratings were presented a number of spatial phase positions in a randomized interoncalcular sequence, using the highest spatial frequency giving reliable responses. Fourier analysis produced threcand second harmonic components of these responses which were plotted against spatial phase. X cell responses were characterized by a strongly phase-

dependent for harmonic which exhibited a clear null point, while Y cell responses included a second harmonic component which was not strongly phase-dependent. Other tests included the duration of the peaks to standing contrast over the receptive field center, the presence or absence of a shift effect, the strength of surround antagonism and size of receptive field centre for a given eccentricity (Einhorn-Czog and Robinet, 1967; Orland et al., 1971; Derrington and Fuchs, 1979). Single-unit data were collected and visual stimuli were produced using computer control (Visual Stimulus System, Cambridge Electronic Design, Cambridge, UK). Stimuli routinely consisted of flashed spots of several diameters, moving bars of length of several lengths or sinusoidal gratings of different spatial frequencies drifted through the receptive field. Stimulus contrast [l(lmax) - l(0) / lmax] was held within a non-saturating range, usually 0.35–0.7, with a mean luminance of 14 cd/m². For quantitative assessment of receptive field parameters the multibandgram technique was used, and all stimuli (e.g. a moving bar of six different lengths) were randomly interchanged within each trial. Our basic experimental paradigms involved establishing control responses to a range of visual stimuli. This was then repeated during continuous iontophoretic application of an inhibitor of nitric oxide synthesis (alone or in combination with L- or D-Arg). To examine the influence of the suppressive activity of NOS inhibitors on excitatory responses evoked by exogenously applied NMDA (Cedroni et al., 1994b), we used phasic iontophoretic application of NMDA with different ejection currents before and during continuous application of either 1-L-NOArg or 1-D-Arg (300 μA alone or in combination with L- or D-Arg). Typically, responses were averaged over five to seven trials and were assessed from the accumulated count in the binned peristimulus time histograms (PSTHs). Pressure application of the nitric oxide donor sodium nitroprusside or SNAP, alone or in combination with NMDA, was also quantitatively examined in the same manner. Magnitude of the drug iontophoretic application current was selected on the basis of initial qualitative observations.

Deafferented animals

In order to minimize excitatory afferent synaptic input to the dlGN and remove presynaptic activity, four animals were decerebrated at the intercollicular level, the visual cortex (areas 17 and 18) was removed by aspiration, and the eye ipsilateral to the recording electrode surgically removed. Bipolar stimulating electrodes were first placed over the optic nerve ipsilateral to the hemisphere to be lesioned, and single monophasic pulses (0.3 ms duration, up to 1 mA) used to activate the dlGN electrophysiologically. Control responses to electrical activation were obtained prior to emulation. Single-unit recording from these animals was begun only after a waiting period of up to 48 h after surgery, when release of neurotransmitter from retinal terminals was completely absent, as judged by the lack of response to stimulation of the optic nerve, even when stimulus current was increased to three times that which had been effective prior to emulation. Cells visually elicited activity in the dlGN layer dominated by the inferior eye was present at this time (insert in Fig. 6).

To control for possible anaesthetic influences, pentobarbitone was used in one animal (1–4 mg/kg i.v., i.m. on room air; the effect of small barbiturate doses on single-unit responses was monitored. At the termination of each experiment, the animal was killed by an overdose of anaesthetic and the brain was removed and prepared for histological reconstruction.)
Results

Effect of application of NOS inhibitors on visual responses

For this study, the effects of intracerebroventricular application of inhibitors of NOS have been tested in a population of 77 cells (X = 35, Y = 38, unclassified = 4) recorded in the A laminae of the LGN. All cells had receptive fields within 12° of the meridian. A typical example of the effect of such application is shown in Figure 1. Here, the responses of an ON-centre X cell to a flashed spot of light of optimum diameter centred on and required to the centre of the receptive field are shown. In the upper row, the control response to visual stimulation alone is compared to those elicited during continuous intracerebroventricular injection of L-NOArg, showing the temporal progression of the effect of NOS blockade. The visual response clearly declined by some 47% after 3 min of application, and remained at this level during the subsequent rest period. The initial transient response into the remaining component were equally affected, and spontaneous activity was reduced. In the middle row, this cell was again tested with the same visual stimulus, after a recovery period of 12 min, and the effect of concomitantly injecting both L-NOArg and L-Arg following visual stimulation is illustrated. In this case, despite an equivalent application of the NOS inhibitor, neither visual response nor spontaneous activity were altered. Finally, after a repeated recovery period, L-NOArg was applied together with the biologically inactive isomer, D-Arg. Here, despite an equivalent application of a compound equal to L-Arg in all but stereospecificity, L-NOArg again produced a marked inhibition of the visual response, reducing it by 50%, producing an effect equivalent to application of L-NOArg alone. Another example is shown in Figure 2. In this case we show the responses of an ON Y cell to flashed spots of light of different diameters before and after application of L-NOArg. As is typical of LGN cells, the control visual responses showed clear response summation followed by attenuation as diameter of the stimulus centred on the centre of the receptive field was increased. During application of the NOS inhibitor, L-NOArg, there were marked decreases in the visual responses (Fig. 2A, P < 0.001, Wilcoxon test at optimum response), which were reversible and not stimulus-selective, completely in accord with our previous findings (Cadenas et al., 1994a). Applied with L-NOArg,
Fig. 2. Diameter-response curves for a ON Y cell in the cat dLGN, stimulated with flashed spots of light of different diameters in degrees of visual space centered on its receptive field (RF). Visual stimuli were randomly intermixed within each trial. Response to stimulation with single spots of light is essentially unchanged in the absence of centrotemporal input (Maukhuri and Silko, 1983), suggesting that these responses are purely retinotopic driven, via NMDA and non-NMDA, isoform-specific excitatory inputs (Wong and Von Krosigk, 1992). (A) Control tuning curve (solid line), and, on the overlay, tuning curve obtained during continuous isophosphoryl reactivity of L-NAME (broken line). (B) Repeated control curve and response during continuous application of L-NAME for 30 min (broken line) and L-Arg (dotted line). The inhibitory effect of L-NAME was completely blocked during L-Arg application but was unaffected by the noncompetitive NOS inhibitor L-Arg. Responses are averaged over seven trials. Small vertical bars, mean ± SEM.

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*Fig. 3. Dose-response curve for NMDA isophosphoryl applied to two dLGN cells. (A) Control response to applications of NMDA, using different concentration currents (mA), solid line, drug pulse duration 3 s and repeated in the presence of a continuous BAPTA-AM of L-NAME at three concentrations of 1 mM, broken line, 10 mM, dotted line, 100 mM, solid line, L-NAME blocked the response to NMDA in a dose-dependent fashion. (B) Responses of the same cell when subsequently treated with NMDA (solid line), and again to NMDA constituted with L-NAME (broken line). Note, however, when NMDA was ejected together with both L-NAME and L-Arg (dotted line), the inhibitory effect of L-NAME was blocked. The pharmacologically inactive isomer D-Arg was without effect (dashed line). L-Arg alone produced no change in the NMDA-evoked responses (dissociated line). (C) Current values were measured period of 10-15 min. Application of a second inhibitor of NOS, L-Mec, to a second cell produced similar effects.

Table 1. Effect of blockade of nitric oxide synthesis on visually evoked responses.
curves showing no lateral shift on the X axis, and resulted in nearly complete suppression of NMDA-induced excitatory responses at the highest concentration. These applications also induced a decrease in spontaneous activity. Figure 3B shows that, like the visual responses, the suppressive effect of the nitric oxideergic application of the most potent l-NOArg solution (10 nM) was almost completely reversed by co-application of l-Arg, but unaffected by co-application of l-Arg. It should be noted that application of l-Arg alone was unable to increase the excitatory responses to NMDA at any point in the NMDA dose-response curve, instead merely rescuing the control level of responses. In Figure 3C, the effects of a second inhibitor of NOS are illustrated. In this case, l-MeArg (10 mM) also markedly suppressed the NMDA-induced excitations. The lack of effect of g-Arg, and effect of l-Arg in blocking but not enhancing the activity of NMDA are again shown, reinforcing the view that the suppressive effects of these compounds are specific, and are the result of competitive inhibition of NOS. On average, NMDA-evoked responses were reduced by 72 ± 8% (SEM) (P < 0.000, Mann-Whitney test). No significant differences between groups were found. This paradigm was tested on a population of 22 cells, and in each case application of l-Arg was unable to reverse the effect of NOS blockade.

Application of NO donors

The histogram in Figure 4A illustrates the effect of pressure application of the nitric oxide donor sodium nitroprusside. Perhaps surprising in view of the action of l-Arg, in this population of single cells (Fig. 4A, filled column, right side), co-application of nitroprusside with NMDA significantly increased firing rates by 30 ± 9% (P < 0.05, Mann-Whitney test), in contrast to the mere reversal of the effect of NOS inhibition by l-Arg. Spontaneous activity (reduced by NOS inhibition) was also significantly increased, by 78 ± 8% (Fig. 4A, filled column, left side). A similar paradigm using the chemically unrelated nitric oxide donor SNAP (Fig. 4B, hatched columns, N = 7) also demonstrates an excitatory effect, with an NMDA-mediated response, increased by 37 ± 10% (P < 0.05, Mann-Whitney test, right side), and on spontaneous activity, increased by 92 ± 17% (left side). In three of these seven cells, visual responses were also tested during SNAP application. Figure 4C illustrates the effect of SNAP application on the visual responses of an ON X cell to a bar of light moved through the receptive field. Control responses are shown on the left, and responses during SNAP application on the right. As with all cells tested, there is a clear enhancement of both the visual and the spontaneous activity.

Comparison with GABA application

Although we have previously demonstrated that the interaction between nitric oxide and NMDA is specific to NMDA, with little or no interaction between nitric oxide and other amino acid and non-amino acid excitants in the dLGN (Coders et al., 1994b), the possibility remains that such specific effects of NOS inhibitors are the result of simple membrane hyperpolarization, lowering the membrane potential below the effective range for voltage-dependent NMDA receptors (Mayer et al., 1984; Norwalk et al., 1984). To control for this, in eight cells we compared the responses to NMDA application before and during application of l-NOArg with those obtained in the presence of continuous application of GABA at levels also effectively reducing spontaneous activity. We suggest that such lowering of firing activity is likely to be the result of GABA- mediated hyperpolarization. These data are exemplified by the responses of the cell shown in Figure 5 to a pulsatile application of NMDA (hatched column). A clear reduction in spontaneous activity was seen during l-NOArg

![Image](image-url)
Fig. 5. Peristimulus time histograms (PSTHs) documenting the cooperative effect of L-NOArg and GABA on NMDA-evoked activity. Responses to a pulse of NMDA alone (90 nM, hatched columns; injection period marked below the X axis in the presence of L-NOArg and GABA application (open columns) or GABA (solid columns). Note that application of L-NOArg and GABA resulted in a similar decrease in spontaneous activity. Although reduced in magnitude, a clear NMDA-evoked response remained during GABA application. Bin size 1 s.

(open columns) or GABA application (solid columns). However, NMDA responses were essentially absent only during L-NOArg application; significant excitatory responses to application of NMDA during GABA application remained.

- **Preganglionic versus postganglionic locus of action**

  Extracellular recordings in vivo cannot directly address the issue of a preganglionic versus a postganglionic locus of action for nitric oxide-mediated regulation of NMDA-induced activity. Nevertheless, we can indirectly investigate this problem. In four animals all main afferent inputs to the dLGN were removed (retina, visual cortical areas 17 and 18 and brainstem; see Materials and methods), and after a waiting period of up to 48 h recordings were obtained from cells ipsilateral to the removed eye. After this waiting period, evoked activity following optic nerve stimulation within the deprived lamina disappeared, while significant visual activity remained in the non-deprived lamina (inset in Fig. 6). Thus we believe transmitter release from the deafferented second terminals within lamina A1 was completely disrupted. NMDA, L-NOArg and nitroprusside were tested in layer A1 on a population of ten cells, whose responses are summarized in the histogram in Figure 6B. In such deafferented animals L-NOArg was essentially ineffective in reducing NMDA-mediated excitation (open column NMDA, hatched column NMDA + L-NOArg, not significantly different, Mann-Whitney test), although the NMDA-mediated responses were also reduced in comparison to control responses in non-deafferented animals (data not shown) and spontaneous activity was also reduced. However, when nitroprusside was applied, NMDA-induced excitatory responses were strikingly increased (filled column, from 41 ± 4.7 to 129 ± 23.5 spikes/s, P < 0.000, Mann-Whitney test).

**Discussion**

The data we have presented above attempt to address a number of issues related to our earlier observations regarding nitric oxide in the cat dLGN. Previously we have shown that iontophoretic application
of the putative inhibitors of the enzyme NOS markedly depressed visual responses (Kemp and Silito, 1982; Hartveit and Heggelund, 1990; Heggelund and Hartvei, 1990; Scharff et al., 1990; Silito et al., 1990a, b; Kwon et al., 1991) were selectively depressed, whereas responses to other excitants, including ACh, were almost unaffected (Cadoro et al., 1994d). A direct action of NO on excitatory amino acid receptors of the type GluR1 blocks EPSCs, consistent with the observation that NO donors reduce glutamatergic responses (Krupa et al., 1990). This observation is consistent with in vitro data showing that NO donors reduce glutamatergic responses (Krupa et al., 1990). The effects of NO donors are not due to a general depressive effect on neuronal excitability, since NO donors do not affect the response to other excitants, such as glutamate or kainate (Krupa et al., 1990).

The presence of NO in the CNS is of particular interest because it is a potent modulator of neuronal excitability and it has been implicated in various physiological and pathological processes. NO is produced by a number of cell types, including neurons, glia, and endothelial cells. It is released as a diffusible gas and can act on distant targets by binding to specific proteins or by interacting with other molecules. NO has been implicated in a variety of neurotransmitter actions, including the modulation of neuronal excitability, synaptic plasticity, and neuronal survival.

The role of NO in visual processing in the LGN has also been investigated. NO donors, such as SNP or S-nitroso-N-acetylpenicillamine, have been shown to increase the responses of LGN neurons to visual stimuli, suggesting a modulation of neuronal excitability by NO. The effects of NO donors are likely mediated by the activation of soluble guanylate cyclase, which increases the production of cGMP, a second messenger that can modulate neuronal excitability.

These findings suggest that NO plays a role in the modulation of neuronal excitability in the LGN, and that it may have a role in the processing of visual information. The precise mechanisms by which NO modulates neuronal excitability are not fully understood, and further studies are needed to elucidate the role of NO in visual processing in the LGN.
have different biological actions (Lipton et al., 1993). Thus, fraction of NO- and reduced form with guanidino group can lead to neurotransmission through the formation of peroxynitrite, whereas nitric oxide alone does not. On the other hand, action of NO (the oxidized form) with thiols groups on the NMDA receptors can lead to neurotransmission by inhibiting Ca2+ influx (Lipton et al., 1993; Lipton and Staudler, 1994). Thus a nitric oxide donor, e.g. nitroprusside, may either have neuroprotective or neurotoxic effects depending on the local redox milieu of the biological system (Lipton et al., 1993; Lipton and Staudler, 1994). However, this problem is much more complicated than was first thought, as it has been recently shown using slices of rat cerebellum and hippocampus that nitric oxide mediates neither acute glutamate neurotoxicity nor neuroprotection (Garwicz and Garwicz, 1994). It is clear that in vivo paradigm differs greatly from those used in the studies related to above and this may, at least in part, contribute to the differences in our data. Other studies, more closely related to our own in vivo work, offer further insight. Do et al. (1994) have described release of vasoactive in the ventrobasal thalamus of awake rats in vivo following physiological stimulation of sensory afferents. While such release should not augment the production of nitric oxide, as judged by the action of L-Arg, we have outlined above, if coupled with a Ca2+-mediated enzyme activation it would markedly increase nitric oxide production. It is possible that nitric oxide has multiple functions within sensory thalamus, Pape and Magaer (1992), in the car LGN in vitro, found the release of nitric oxide on thalamic neurones had a direct postsynaptic effect which caused depolarization from the membrane resting potential associated with a decrease in input resistance, which appeared only at membrane potentials negative to -65 mV. These small depolarizations appeared to act via the GABAergic secondary messenger system and are related to control of oscillatory firing patterns. This GOMP-mediated action of nitric oxide may be involved in the control of different patterns of electrographic activity during various states of the sleep-wake cycle (Pape and Magaer, 1992). However, we have previously shown that the effects of NOS blockade outlined above do not operate via control of the GOMP cascade, since the salidate GOMP analog 8-bromo-GMP (the compound used by Pape and Magaer (1992) did not affect NMDA-mediated excitation (Colquhoun et al., 1994) or, as we have now shown above, nitric the effect of substances like nitroprusside or SNA P.

In summary, the most parsimonious view of our data suggests that, within the car LGN, where NOS is located only within the terminals of parabrachial input (Billard et al., 1993), i.e. action of NO is to enhance or permit full expression of NMDA-mediated activity. At the level of the LGN there are three possible sites for nitric oxide action cells within the nucleus, presynaptic terminals impinging on these cells, or both. Within the cerebral cortex it has been suggested that nigro-cortical or mesolimbic neurones release glutamate subsequent to NMDA receptor activation, in a study confirming a facilitatory action of nitric oxide on NMDA function at this level enhancing presynaptic NMDA control of transmitter release (Montague et al., 1994). Direct action on the regulation of neurotransmitter release have been reported from a number of brain areas, including the striatum (Black et al., 1994), the hippocampus (Lamont et al., 1992) and the medial preoptic area (Lermus and Jull, 1993). However, our data using desensitized animals clearly suggest a straightforward postsynaptic action of nitric oxide at these sites with the action of sodium nitroprusside. We have illustrated this diagrammatically in Figure 7. Clearly, the highly diffusible gas nitric oxide may act in the proximity of the synaptic area of the parabrachial terminals, diffusing to act on nitrovasculature or other synapses utilizing NMDA receptors, perhaps also on neighbour-}

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**Abbreviations**

ACH  acetylcholine

EGG  electroencephalogram

ECG  electrocardiogram

cGMP  cyclic guanosine-3',5'-monophosphate

CNS  central nervous system

dLGN  dorsal lateral geniculate nucleus

GABA  y-aminobutyric acid

Δ-Arg  L-arginine

Δ-Arg  L-arginine

Δ-LArg  N6-methyl-L-arginine

Δ-LNDAmp  N6-sydroxy-L-arginine

NMDA  N-methyl-D-aspartate

NOS  nitric oxide synthase

PSTH  peri-stimulus time histogram

SNAP  S-nitrosoglutathione
t

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