Source of Inappropriate Receptive Fields in Cortical Somatotopic Maps From Rats That Sustained Neonatal Forelimb Removal

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Lane, Richard D., Andrey S. Stojic, Herbert P. Killackey, and Robert W. Rhoades. Source of inappropriate receptive fields in cortical somatotopic maps from rats that sustained neonatal forelimb removal. J. Neurophysiol. 81: 625–633, 1999. Previously this laboratory demonstrated that forelimb removal at birth in rats results in the invasion of the cuneate nucleus by sciatic nerve axons and the development of cuneothalamic cells with receptive fields that include both the forelimb-stump and the hindlimb. However, unit-cluster recordings from primary somatosensory cortex (SI) of these animals revealed few sites in the forelimb-stump representation where responses to hindlimb stimulation also could be recorded. Recently we reported that hindlimb inputs to the SI forelimb-stump representation are suppressed functionally in neonatally amputated rats and that GABAergic inhibition is involved in this process. The present study was undertaken to assess the role that intracortical projections from the SI hindlimb representation may play in the functional reorganization of the SI forelimb-stump field in these animals. The SI forelimb-stump representation was mapped during γ-aminobutyric acid (GABA) receptor blockade, both before and after electrolytic destruction of the SI hindlimb representation. Analysis of eight amputated rats showed that 75.8% of 264 stump recording sites possessed hindlimb receptive fields before destruction of the SI hindlimb. After the lesions, significantly fewer sites (13.2% of 197) were responsive to hindlimb stimulation (P < 0.0001). Electrolytic destruction of the SI lower-jaw representation in four additional control rats with neonatal forelimb amputation did not significantly reduce the percentage of hindlimb-responsive sites in the SI stump field during GABA-receptor blockade (P = 0.98). Similar results were obtained from three manipulated rats in which the SI hindlimb representation was silenced temporarily with a local cobalt chloride injection. Analysis of response latencies to sciatic nerve stimulation in the hindlimb and forelimb-stump representations suggested that the intracortical pathway(s) mediating the hindlimb responses in the forelimb-stump field may be polysynaptic. The mean latency to sciatic nerve stimulation at responsive sites in the GABA-receptor blocked SI stump representation of neonatally amputated rats was significantly longer than that for recording sites in the hindlimb representation [26.3 ± 8.1 (SD) ms vs. 10.8 ± 2.4 ms, respectively, P < 0.0001]. These results suggest that hindlimb input to the SI forelimb-stump representation detected in GABA-blocked cortices of neonatally amputated rats originates primarily from the SI hindlimb representation.

INTRODUCTION

In a previous report, we described an experimental manipulation (neonatal forelimb removal) in rats that produces a dramatic reorganization of the dorsal column-medial lemniscal pathway such that a significant percentage of cuneate nucleus neurons express hindlimb receptive fields in addition to those from the forelimb-stump region (Lane et al. 1995). These hindlimb receptive fields appear to be suppressed functionally at higher somatosensory centers because very few can be detected in the primary somatosensory cortex (SI) forelimb-stump representation. The mechanism underlying this suppression appears to involve γ-aminobutyric acid (GABA) mediated by both GABA_A and GABA_B receptors, because treatment of the cortices with the appropriate GABA antagonists revealed robust hindlimb receptive fields throughout much of the SI forelimb-stump representation (Lane et al. 1997). A recent study used primarily anatomic methods to examine three possible sources of this hindlimb input: intracortical connections in SI, thalamocortical afferents arising from the hindlimb representation of the ventroposterior lateral nucleus (VPL), and thalamocortical afferents arising from the forelimb-stump representation of VPL (Stojic et al. 1998). The results of that study indicated that the anatomic arrangement of the thalamocortical and intracortical fibers in the neonatally amputated rats was normal. These findings were consistent with the conclusion that the GABA-suppressed hindlimb inputs to the SI forelimb-stump representation were conveyed via the thalamocortical neurons in the forelimb-stump representation of the VPL. This possibility is surprising for two reasons. First, single-unit recordings from the VPL of neonatally manipulated rats indicated that a relatively small but significant population of VPL neurons (19%) express a hindlimb as well as a stump receptive field (Stojic et al. 1998). In comparison, more than twice as many of the SI stump field recording sites (44%) express hindlimb receptive fields in the GABA-receptor-blocked cortices (Lane et al. 1997). Second, a number of studies have implicated preexisting intracortical connections (Hirsch and Gilbert 1993; Jenkins et al. 1990; Li and Waters 1996; Li et al. 1996; Smits et al. 1991; Wall 1988) as well as corticocortical connections that emerge after peripheral deafferentation (Darian-Smith and Gilbert 1994), as key elements in functional cortical reorganization in both the visual and somatosensory systems. The present experiments were undertaken to test the role of thalamocortical fibers versus intracortical connections in conveying hindlimb input to the SI stump representation in the GABA-receptor-blocked cortices of neonatally manipulated rats. Specifically, we examined the consequences of removing the SI hindlimb representation, a potential source of intracortical input, on the expression of hindlimb receptive fields in the GABA-receptor-blocked SI stump field.
METHODS

Neonatal forelimb removal

Pups >12 h old were anesthetized by hypothermia until immobile. The left forelimb was amputated with iridectomy scissors below the shoulder and the brachial artery sealed by electrocautery. The stump was infiltrated with local anesthetic (0.7% bupivacaine), and the skin was closed with cyanoacrylate adhesive. The pups were warmed, returned to their mothers, and used in recording experiments when they reached >60 days of age.

Recordings from SI

Standard multiple-unit recording and receptive-field mapping techniques were used to assess the representation of the body surface in the SI cortex (Lane et al. 1995, 1997). Recordings in animals that sustained neonatal forelimb removals were made from the right cerebellar cortex, contralateral to the amputation. Recordings from normal animals were made from the right cerebellar cortex. Rats initially were anesthetized with a combination of ketamine (100 mg/kg) and xylazine (20 mg/kg), the trachea was cannulated, and the left brachial plexus and sciatic nerves were exposed. The rats were placed in a stereotaxic head holder and mechanically ventilated. A bipolar stimulating electrode was placed on the brachial plexus just proximal to the origin of the median, ulnar, and radial nerves and another was placed on the sciatic nerve ~15 mm distal to the sciatic notch. A midline incision was made in the scalp, the skull overlying the dorsal cortex was removed, and the dura was incised and reflected. The surface of the cortex was photographed at ×44 to record the placement of microelectrode penetrations. The cortical surface was kept moist by applying culture medium (Dulbecco’s modified essential medium) warmed to 37°C. Rats were maintained in a state of light anesthesia for the duration of the recording session with periodic injections of urethan (200 mg ip).

Unit clusters and occasional single units were recorded with varnish-coated tungsten microelectrodes (Z = 0.9–1.3 MΩ) and cutaneous receptive fields were defined in the manner previously described by Rhoades et al. (1993) and Lane et al. (1995, 1997). Electrode penetrations spaced ~300 μm apart were made in a rectangular array, and multitunit activity was recorded at depths between 500 and 750 μm (the approximate depth of lamina IV). Cutaneous receptive fields were mapped with tactile stimuli delivered with brushes and blunt probes. Response latencies to brachial plexus or sciatic nerve electrical stimulation (0.1-ms pulses ranging from 3 to 12 V) were tested at recording sites characterized as possessing a forelimb-stump or hindlimb receptive field. Latency values were defined on the oscilloscope traces as the time between the beginning of the brachial plexus or sciatic nerve stimulation artifact and the beginning of the cortical response. In addition to the neonatally manipulated rats, cortical response latencies to brachial plexus and sciatic nerve electrical stimulation were measured in two normal rats before and during γ-aminobutyric acid (GABA)-receptor blockade.

As illustrated in Fig. 1 (experiment 1), the SI forelimb-stump and hindlimb representations in cortex were mapped with multitunit recording electrodes as described in the preceding text (map A). In four cases, the SI lower-jaw representation was mapped in addition to the forelimb-stump and hindlimb fields. After the initial mapping was completed, 30 μl of a GABA-receptor-blocker solution containing equal parts of 50 μM bicuculline methiodide and 50 μM phaclofen (both supplied by Research Biochemicals International) was applied to the surface of the cortex as previously described (Lane et al. 1997). After a delay of ~15 min, the stump region was remapped (map B) in the manner described earlier. Between 30 and 50 sites in the forelimb-stump representation were tested during each mapping, and the same sites were retested after the addition of the GABA-receptor blockers. The percentage of forelimb-stump sites with hindlimb receptive fields, after completion of the second map, either the SI hindlimb (n = 8) or lower-jaw (n = 4) representation was lesioned electrolytically. These representations were destroyed by making multiple penetrations with a metal electrode ~300 μm apart through the first 800 μm of the cortex while maintaining a constant 4 V DC. The completeness of the lesion was determined later by examining cytochrome oxidase (CO) stained sections of the cortices. The GABA-receptor blockers then were reapplied to the cortex as before, and the forelimb-stump representation was remapped a third time (map C). In several experiments, a recording electrode was positioned near the center of the stump representation and left undisturbed during the subsequent treatments. At the end of the mapping experiment, the animal was given a lethal dose of carbon dioxide and perfused with heparinized saline followed by 4% paraformaldehyde dissolved in sodium phosphate buffer (pH 7.4). The cortex was removed, flattened, and cut into 50-μm sections. Sections were stained for CO by the method of Wong-Riley (1979).

Temporary inactivation of the SI hindlimb representation with cobalt chloride

In another series of experiments (Fig. 1, experiment 2), the stump and hindlimb representations of three neonatally amputated rats were mapped before and after treatment with the GABA blockers (map A). For the remainder of the experiment, a recording electrode was positioned near the center of the SI forelimb-stump representation at a location (site 1) that was responsive to both stump and hindlimb tactile stimulation. A second recording electrode was positioned in the SI hindlimb representation at a location (site 2) that was responsive to hindlimb tactile stimulation. A second recording electrode was positioned in the SI hindlimb representation at a location (site 2) that was responsive to hindlimb tactile stimulation. After characterizing the receptive fields at sites 1 and 2 (trace series 1), a saline solution containing 0.2 μl of cobalt chloride (30 mM) was injected into each of six sites in the SI hindlimb representation. After confirming that the cobalt chloride injections suppressed the sensory responses to hindlimb stimulation at site 2, the responses to tactile stimulation recorded at site 1 were evaluated (trace series 2). Once activity had returned to the hindlimb representation as assayed at site 2, the responses recorded at site 1 were reevaluated (trace series 3). GABA-receptor blockade was maintained throughout the latter part of the experiment. At the end of

FIG. 1. Diagrams of the experimental paradigms followed in this investigation. Experiment 1 shows the sequence of cortical mapping that was performed under normal conditions, during γ-aminobutyric acid (GABA)-receptor blockade and after electrolytic lesion of the primary somatosensory cortex (SI) hindlimb or lower-jaw representation while maintaining GABA-receptor blockade. Experiment 2 shows the sequence of cortical mapping followed by recordings collected from 2 fixed electrodes, 1 located in the stump representation (site 1) and another in the hindlimb representation (site 2). Receptive-field properties assayed at these 2 sites then were measured before (trace series 1), during (trace series 2), and after (trace series 3) CoCl2 silencing of the SI hindlimb representation while maintaining GABA-receptor blockade.
the recording session, rats were killed with carbon dioxide, perfused, and the cortices processed for CO staining as described earlier.

**Statistical analysis**

An analysis of variance (ANOVA) was used to test for significant differences between the percentages of sites with hindlimb receptive fields in the forelimb-stump representation under the various conditions described in the previous section and to compare the differences in forelimb-stump and hindlimb latency times measured under these conditions. When the ANOVA demonstrated significant ($P < 0.05$) between-group differences, a Scheffe test was performed to identify experimental groups with significantly different means. In two cases, specific latencies were compared using Student’s $t$-test.

**RESULTS**

Effects of lesioning the hindlimb or lower-jaw representations on expression of hindlimb receptive fields in the stump representation of neonatally amputated rats

The organization of the stump and hindlimb representations within SI in two adult rats that sustained neonatal forelimb amputation are shown in Fig. 2, A and E. Within the stump representation, few sites responded to hindlimb stimulation. Of 271 sites that responded to stimulation of the stump in eight neonatally manipulated rats, only 3.7% ($n = 10$, Fig. 2, △) also could be activated by stimulation of the hindlimb (Fig. 3A, AVG bar). Figure 2, B and F, shows the stump representations from the same animals during application of bicuculline and phaclofen. There was a large increase in the number of sites within the stump representations with receptive fields that include the hindlimb. C: electrolytic lesion of the hindlimb representation greatly reduced the numbers of stump sites with dual stump and hindlimb receptive fields. However, electrolytic lesion of the lower-jaw representation in G did not affect the expression of dual stump and hindlimb receptive fields. D and H are cytochrome oxidase (CO)-stained tangential sections of the SI cortices from those rats that show the lesioned areas. Orientation arrows in A: anterior (a) and lateral (l) directions; arrows apply to all 4 cortical maps. Bar = 1 mm.
lesions. Of these, only 13.2% (76 of 112) still possessed hindlimb responsiveness (Fig. 3, AVG bars, \( P = 0.98 \) compared with prelesioned stump with GABA-receptor blockade). Figure 2, E–H, shows the maps and lesions from one of these animals. Figure 5 shows the traces from the stump representation from one of these control animals. In this case, the lower-jaw representation was lesioned and the postlesion traces are shown in series 3. Note that the hindlimb response in the GABA-receptor-blocked cortex is still present after lesioning the lower-jaw representation (Fig. 5, series 3, traces 2 and 4).

Temporary inactivation of the SI hindlimb representation with cobalt chloride

The role of the cortical hindlimb representation in the functional reorganization of the stump field was evaluated further by reversible inactivation of the hindlimb response with cobalt chloride. (Figs. 6 and 7). Figure 7A shows the traces obtained from the recording electrode positioned in the stump representation at site 1, whereas Fig. 7B presents the traces obtained from the electrode located at site 2 in the hindlimb representation. Before the cobalt chloride treatment, the GABA-receptor-blocked stump site showed robust responses to both forelimb and hindlimb stimulation (Fig. 7A, series 1). During

were previously hindlimb-responsive were assessed after the lesions. Of these, only 13.2% (10 of 76) still possessed hindlimb responsiveness after lesions of the SI hindlimb region (Fig. 3A, AVG bar). All of these sites remained responsive to stump stimulation after the lesioning of the hindlimb representation. Although the effect of hindlimb lesions on the percent of sites possessing hindlimb responsivity varied among individual animals, no correlation was apparent between this value and the completeness of the hindlimb lesion as seen on the CO-stained cortical sections (see Fig. 2D for example of lesions).

In a series of control experiments, 116 sites were evaluated in four manipulated rats; 65.5% (76 of 116) displayed hindlimb receptive fields in stump recording sites during GABA-receptor blockade. After electrolytic lesions of the lower-jaw representation, 64.3% (72 of 112) still possessed hindlimb responsiveness (Fig. 3, AVG bars, \( P = 0.98 \) compared with prelesioned stump with GABA-receptor blockade). Figure 2, E–H, shows the maps and lesions from one of these animals. Figure 5 shows the traces from the stump representation from one of these control animals. In this case, the lower-jaw representation was lesioned and the postlesion traces are shown in series 3. Note that the hindlimb response in the GABA-receptor-blocked cortex is still present after lesioning the lower-jaw representation (Fig. 5, series 3, traces 2 and 4).

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cobalt chloride treatment of the hindlimb representation, the neuronal responses evoked by the stimulation of the hindlimb disappeared in both the hindlimb representation (Fig. 7B, series 2, traces 2 and 4) as well as in the SI stump representation (Fig. 7A, series 2, traces 2 and 4). After the cobalt chloride effect had worn off, as indicated by the return of the hindlimb responsivity in the hindlimb representation (Fig. 7B, series 3, traces 2 and 4), the hindlimb responsivity also had returned to the stump representation as shown in Fig. 7A (series 3, traces 2 and 4). The borders of the mapped hindlimb and stump representations, the positions of the two recording sites, and the cobalt chloride injection sites in the hindlimb representation were verified by the CO pattern obtained from tangential sections of this brain (Fig. 6).

**Comparison of forelimb-stump and hindlimb latencies in normal and manipulated rats**

The responses evoked by sciatic nerve stimulation at recording sites in the SI stump representation had very long latencies compared with both responses to stimulation of this nerve in the hindlimb representation and response to brachial plexus stimulation in the stump field. The average latency to sciatic nerve stimulation in the SI hindlimb representation measured in two normal animals was 12.7 ± 1.4 (SD) ms (n = 40) whereas that measured in seven neonatally amputated animals was significantly (P < 0.0001, Student’s t-test for independent samples) shorter (10.5 ± 2.0 ms, n = 74). Application of the GABA-receptor blockers to the cortex did not have a significant effect on these values (13.3 ± 1.8 ms and 10.8 ± 2.4 ms, respectively) (see Fig. 8, A, B, and G). The average latencies to brachial plexus stimulation in the forelimb representation in normal rats with and without GABA-receptor blockade (9.4 ± 1.6 ms, n = 122 and 10.3 ± 2.1 ms, n = 120, respectively) were similar to the latencies measured under comparable conditions in the stump representation of neonatally manipulated rats (10.0 ± 2.2 ms, n = 78 and 9.6 ± 2.7 ms, n = 77, respectively; Fig. 8, C, D, and G). The average latency (26.3 ± 8.1 ms, n = 169) measured in the GABA-receptor-blocked stump cortex of neonatally amputated rats in response to sciatic nerve stimulation was significantly (P < 0.0001) longer than many of the previously listed values (Fig. 8, E and G). The average latency of those sites (n = 22) in the GABA-receptor-blocked stump representation that maintained hindlimb responsivity after lesion of the hindlimb representation was 19.1 ± 7.8 ms (Fig. 8F). This latency was not significantly different from that for the same sites before the lesion (19.5 ± 5.6 ms, P = 0.750, paired Student’s t-test).

**DISCUSSION**

The results of the present study indicate that the hindlimb input to the SI forelimb-stump representation detected in GABA-receptor-blocked cortices of neonatally forelimb amputated rats reaches this site via a pathway that includes the SI hindlimb representation. However, before considering these results further, several important technical limitations of our approach must be considered.

**Technical limitations**

The present study used multiple electrolytic lesions to destroy the SI hindlimb representation. It is possible that these lesions produced nonspecific effects (e.g., ischemia), which altered the properties of SI forelimb-stump neurons. However, the fact that SI lower-jaw representation lesions had no effect on these cells argues against nonspecific effects producing the observed changes. This view was supported further by the observation that reversible silencing of the SI hindlimb cortex by chemical means (CoCl₂) produced a similar effect at the stump recording sites. Regarding the CoCl₂ experiments, it should be noted that the effects observed were measured at a single pair of sites in the forelimb-stump and hindlimb representations and not across mul-

**FIG. 6.** Comparison of the electrophysiologically mapped and cytochrome oxidase (CO)-histochemically defined borders of a neonatally manipulated rat that received cobalt chloride injections (indicated by Xs) in the hindlimb representation to temporarily silence that region. Paired photomicrographs of the cortical surfaces show the map (A) of the stump representation and the corresponding tangential sections stained for CO (B). Continuous recordings were taken from site 1 in the stump representation and site 2 in the hindlimb representation. Discrepancy between A and B in the location of the hindlimb border and the cobalt chloride injection sites likely was produced when the cortex was flattened before sectioning. Orientation arrows in A: anterior (a) and lateral (l) directions. Bar = 1 mm.
multiple sites in the forelimb-stump representation as was the case in the lesion study. Measuring the electrophysiological effects at a single site in the hindlimb representation leaves open the possibility that the CoCl₂ injections did not silence all of the hindlimb cortex. Mooney et al. (1992) observed that a single 25-nl injection of 10 mM CoCl₂ in the superior colliculus of a hamster silenced the cortical stump representation. Previous work by 15 min (compare series 3 with 1, traces 2 and 4). Local injection of cobalt chloride into the cortex eliminated the hindlimb response (series 2, traces 2 and 4). However, the responsivity of site 1 as well as that of site 2 to hindlimb stimulation returned after ~15 min (compare series 3 with 1, traces 2 and 4). Calibration: 0.2 mV on the vertical scale for all traces, 5 ms on the horizontal scale for traces 1 and 2, and 50 ms for traces 3 and 4.

Fig. 7. A: traces recorded from a micro-electrode positioned at site 1 (Fig. 6) in the cortical stump representation of an adult rat that sustained neonatal amputation of the contralateral forelimb. Cortex was treated continually with the GABA-receptor antagonists throughout the recording period. Traces were recorded before [series 1 (+GABA antagonists)], during cobalt chloride silencing of the hindlimb representation [series 2 (+CoCl₂ in HL Rep.)], and after the cobalt chloride effect had worn off [series 3 (+GABA antagonists)]. Traces are responses to electrical and cutaneous stimulation as described in Fig. 3. Temporary silencing of the hindlimb representation eliminated the hindlimb response to either electrical (series 2, trace 2) or cutaneous (series 2, trace 4) stimulation. B: continuous recording from site 2 (shown in Fig. 6) near the center of the hindlimb representation demonstrates the direct effect of treating this region with cobalt chloride. As expected, initially this site is responsive to hindlimb stimulation (series 1, traces 2 and 4) but not to forelimb stimulation (series 1, traces 1 and 3). Local injection of cobalt chloride into the cortex eliminated the hindlimb response (series 2, traces 2 and 4). However, the responsivity of site 1 as well as that of site 2 to hindlimb stimulation returned after ~15 min (compare series 3 with 1, traces 2 and 4). Calibration: 0.2 mV on the vertical scale for all traces, 5 ms on the horizontal scale for traces 1 and 2, and 50 ms for traces 3 and 4.

Role of intracortical neurons in cortical reorganization

Intracortical neurons appear to play a major role in transmitting the hindlimb receptive-field information from the SI hindlimb representation to the stump representation. Previous...
work has indicated that intracortical reorganization may be responsible for substantial rearrangements of adult cortical representations in response to injury (e.g., Darian-Smith and Gilbert 1994; Das and Gilbert 1995; Doetsch et al. 1988; Jacobs and Donoghue 1991; Pons et al. 1991). However, the intracortical reorganization apparent in the present study ap-
pears to differ from that described in previous reports. We (Stojic et al. 1998) have been unable to detect any significant anatomic evidence of direct connections between the SI hindlimb and stump representations in neonatally amputated rats. Our results thus suggest that a polysynaptic intracortical pathway, perhaps involving dysgranular cortex, may underlie the functional reorganization observed in our experiments. It is possible that neonatal forelimb amputation simply increases the effectiveness of existing polysynaptic connections between the hindlimb and stump representations. Evidence of significant hindlimb inputs to the SI forelimb field of normal rats has been reported in an earlier study from this lab (Lane et al. 1997). Before GABA-receptor blockade, 2.7% of all SI forelimb recording sites express hindlimb inputs, and this value increases to 11.7% under GABA blockade. This suggests that neonatal forelimb amputation may act by enhancing the normal expression of inappropriate inputs in the SI forelimb-stump representation.

Support for a polysynaptic pathway between the SI hindlimb and stump representations comes from the long latency values measured in the GABA-receptor blocked stump representation in response to sciatic nerve stimulation (Fig. 5E). The average latency to sciatic-nerve stimulation in hindlimb cortex of neonatally amputated rats is 11 ms, whereas that in the stump representation is 26 ms. This large time interval would allow multiple intracortical neurons to be present in the pathway between the hindlimb and stump representation. It is worth noting that the very long latencies of hindlimb-response neurons in the cortical stump representation are consistent with those reported for neurons with altered receptive fields in other studies. Faggin et al. (1997) recently reported that in response to mechanical stimulation of facial whiskers, the average latency of unmasked sensory responses in the somatosensory cortices of rats that received subcutaneous injections of lidocaine was 19.6 ms. Schroeder et al. (1995) observed that in response to electrical stimulation of the forearm skin, a similar long latency of ~30 ms for peak current flow for the nondominant radial nerve input to area 3b in squirrel monkey versus 12 ms for the dominant ulnar and median nerve inputs. Ebner and Armstrong-James (1990) observed that the center receptive field of layer IV cells in the SI vibrissae representation of rats has a latency of 7–10 ms in response to whisker deflection, but the surround receptive field has a latency of 15–40 ms in response to adjacent whisker deflection. Like the hindlimb responses in the stump representation of neonatally amputated rats, the surround receptive field for vibrissae sensitive neurons depends on intracortical connections (Armstrong-James et al. 1989; Fox 1994).

The present results raise the question: why do the neonatally amputated rats possess a physiological demonstrable connection between the SI hindlimb and the SI stump representation that is silenced by GABAergic neurons? Perhaps this phenomenon is a result of alterations in the pattern of intracortical connections in response to the nerve injury and/or the associated change in afferent input caused by the neonatal forelimb amputation. In the visual system, sensitivity of the architecture of intracortical fibers to changes in visual experience during postnatal development has been observed in cat striate cortex (Callaway and Katz 1991; Lowel and Singer 1992; Lubke and Albus 1992; Luhmann et al. 1986; Price and Blakemore 1985). In the somatosensory system, infraorbital nerve lesion on postnatal day 7, after the whisker pattern is established, produces a drastic reduction in intracortical projections within the mouse barrel cortex (McCasland et al. 1992). This indicates that the normal murine pattern of intracortical connections is dependent on sensory input. In contrast, Rhoades et al. (1996) found that neither silencing of cortical synaptic activity or transection of the infraorbital nerve on postnatal day 7 (after thalamocortical afferent patterns are established) has an effect on the pattern of vibrissae-related intracortical projections within rat SI. However, infraorbital nerve section on day of birth, before the establishment of the thalamocortical afferent pattern in the cortex, profoundly affects the patterning of intracortical connections. On the basis of these studies, one would expect that limb amputation on the day of birth would produce changes in the patterns of both thalamocortical and intracortical fibers within the rat SI stump representation, and this may well be the case. Unfortunately, these studies do not tell us what changes to expect between two physically separated representations, the hindlimb and stump.

Assuming the presumptive excitatory hindlimb to stump representation pathway is established early in postnatal development, the GABAergic inhibitory system, which appears to develop more slowly than the excitatory system (Micheva and Beaulieu 1997), could, via Hebbian mechanisms (Hebb 1949), suppress this connection in the stump region due to its lack of synchrony with the more abundant stump responsive afferents in this region. However, unlike other systems in which Hebbian mechanisms have been proposed to explain development and/or plasticity of connections (Hubel et al. 1977; Shatz and Stryker 1978; Wiesel and Hubel 1970), the suppression of hindlimb information in the stump representation does not appear to involve a loss or retraction of the pathway, which can support expression of functional reorganization. Rather it appears that hindlimb inputs to the stump field can make a significant number of effective synaptic connections, but these connections are suppressed functionally through GABA-inhibitory mechanisms. Thus the preferential expression of stump inputs over hindlimb information may result not only from the competition between the two groups of excitatory inputs in a classical Hebbian fashion. Instead, the suppression of hindlimb inputs may involve the stump afferents’ ability to effectively steer the development of inhibitory circuits within the stump field to permit the expression of stump inputs over the more inappropriate hindlimb inputs. What factors that would permit the development of this inhibition remain, as of yet, unclear and require further investigation.

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