

EFFECT OF THE NMDA RECEPTOR ANTAGONIST MK-801
ON RECOVERY FROM SPINAL CORD INJURY IN
RATS GIVEN UNCONTROLLABLE STIMULATION

A Senior Honors Thesis

by

CHRISTINE ELIZABETH PETRICH

Submitted to the Office of Honors Programs
& Academic Scholarships
Texas A&M University
In partial fulfillment of the requirements of the

UNIVERSITY UNDERGRADUATE
RESEARCH FELLOWS

April 2006

Major: Psychology

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April 2006

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ABSTRACT

Effect of the NMDA Receptor Antagonist MK-801 on Recovery From Spinal Cord Injury in Rats Given Uncontrollable Stimulation (April 2006)

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The eventual outcome of spinal cord injury is largely influenced by damage that occurs after the injury. Damaged connections between spinal cord cells and the brain allow a positive feedback mechanism to go unchecked when activated by ascending pain messages. Over-excitation then causes secondary damage. This study examines whether a pharmacological manipulation that should attenuate over-excitation reduces the adverse effects of shock treatment. Rats received spinal impact injuries and, the next day, were given the NMDA receptor antagonist MK-801 (0.08 mg/kg, i.p.) or its vehicle before receiving either a bout of uncontrollable stimulation or identical treatment without the stimulation itself. Their hindlimb motor activity was monitored for 21 days. Results indicate a significant effect of the drug on rats that received uncontrollable stimulation. The study has clinical implications for the treatment of spinal cord injuries in humans.

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INTRODUCTION¹

Spinal cord injury can have devastating long-term consequences, including intractable pain, paralysis, and loss of sensation, which disrupt the ability to function and may cause feelings of despair. The last decade has brought increased hope in behavioral, physiological, and pharmacological procedures to restore some function and reduce injury-related pain. Spinal cord systems have been shown to have the plasticity needed to reestablish neural connections and to adapt to new environmental and physiological conditions (e.g., Barbeau, Ladouceur, Norman, Pepin, & Leroux, 1999; Carrier, Brustein, & Rossignol, 1997; Cheng, Cao, & Olson, 1996; Edgerton, Roy, de Leon, Tillakaratne, & Hodgson, 1997; Hodgson, Roy, de Leon, Dobkin, & Edgerton, 1994; Hulsebosch, Hains, Waldrep, & Young, 2000; Wernig, Muller, Nanassy, & Cagol, 1995).

Several studies have provided evidence for spinal cord plasticity. After spinal cord injury in either a cat or a human, behavioral training can reestablish stepping on a treadmill, and the spinal circuitry that underlies stepping can “learn” or adapt to new environmental relations (Carrier et al., 1997; Edgerton et al., 1997; Hodgson et al., 1994; Rossignol, 1996; Wernig et al., 1995). On the other hand, plasticity can also have negative effects. Neuropathic pain can arise when painful stimuli from injury or inflammation sensitize neurons of the spinal cord, a phenomenon called central

¹ This thesis follows the style and format of *Behavioral Neuroscience*.

sensitization (Coderre, 1993; Dickenson, 1996; Willis, Sluka, Rees, & Westlund, 1996; Woolf, 1983, 1984).

In central sensitization, damage to descending modulatory tracts allows afferent input to lead to glutamate over-excitation in the spinal cord and thus to enhance secondary damage (Beattie, Farooqui, & Bresnahan, 2000). Because of this, uncontrollable stimulation after spinal cord injury impairs recovery, as demonstrated by Grau and colleagues (2004). In their study, spinally contused rats that received uncontrollable legshock had poor recovery, with respect to locomotor ability, bladder function, limb rigidity (spasticity), weight gain, and mortality, relative to both unshocked rats and rats that received controllable (response-contingent) legshock. Rats that received controllable shock exhibited normal recovery, indicating that lack of instrumental control is crucial for the deleterious consequences of nociceptive stimulation.

Evidence suggests that the mechanisms for this sort of cellular memory are similar to those that govern storage of information in the hippocampus (Ji, Kohno, Moore, & Woolf, 2003; Willis, 2002). The hippocampus utilizes long-term potentiation, which is mediated by NMDA receptors in concert with other molecules. Joynes, Janjua, and Grau (2004) used a spinal transection model to demonstrate the importance of the NMDA receptor in spinal cord learning. Rats' spinal cords were transected (severed), and an NMDA receptor antagonist or its vehicle was administered. Subjects then received response-contingent shock. Vehicle-treated rats learned to keep their legs in a flexed position, whereas the NMDA receptor antagonist inhibited learning.

Learning to keep the leg in a flexed position can also be blocked by prior exposure to noncontingent shock (Joynes & Grau, 2004). Ferguson and colleagues (2006) went on to show that pretreatment with MK-801, a noncompetitive NMDA receptor antagonist, can block this deficit. They suggest that uncontrollable shock blocks subsequent learning because it saturates neural plasticity. Neural plasticity is the end result of central sensitization, which diffusely enhances neural excitability within the spinal cord. Therefore, along with the aforementioned damage associated with central sensitization, it seems to also inhibit further spinal learning and, potentially, the repair of spinal connections.

The present experiment therefore tested whether the NMDA receptor antagonist MK-801 protects spinally contused subjects from the adverse effects of uncontrollable stimulation.

METHODS

Subjects

Subjects were 44 male Sprague-Dawley rats obtained from Harlan (Houston, Texas), weighing 300–390 g. They were 90–110 days old and were housed individually in Plexiglas bins (45.7 [length] x 23.5 [width] x 20.3 [height] cm). A 12/12 hr light/dark cycle was maintained in their colony (8 a.m. on/8 p.m. off), and food and water were available ad libitum. Extra bedding was added to each cage after surgery to facilitate access to food and water. Additionally the short rat sipper tubes of water were replaced with long mouse sipper tubes to allow for easy reaching without rearing. Subjects were weighed regularly and checked daily for signs of spasticity and autophagia. Spasticity was identified if a subject's limb was fixed in an extended position and was resistant to movement. Subjects' bladders were expressed in the morning (8–9:30 a.m.) and evening (6–7:30 p.m.) until they regained bladder control, which was defined operationally as having an empty bladder, with no more than a few drops of urine, at both times of expression for three consecutive days. All treatments and testing occurred between 10 a.m. and 5 p.m.

The institutional animal care committee at Texas A&M University reviewed and approved all of the experimental protocols, which follow all NIH guidelines for the care and use of animal subjects.

Surgery

Rats received a contusion injury with the MASCIS device developed by Bruner (1992) and Constantini and Young (1994). Each subject was first anesthetized with pentobarbital (50 mg/kg, i.p.) to reach a stable, comparable level of anesthesia, as verified by assessment of spinal reflexes. An area extending approximately 4.5 cm rostral and caudal to the site of injury was shaved and disinfected with iodine. Subjects' eyes were spread with petroleum jelly to maintain moisture in the absence of blinking. A 7.0-cm incision was made over the vertebral column, and an incision was made on each side of the vertebral column, extending approximately 3.0 cm rostral and caudal to the T10–T11 (thoracic vertebrae 10–11) segment. Next the vertebrae dorsal and medial to T10–T11 were cleared to expose the spinal tissue. The vertebral column was secured with the MASCIS device, and the 10-g impactor with 3-mm tip was dropped 12.5 mm to produce a moderate injury. The subject was then removed from the MASCIS device and placed on a heating pad, and its wound was closed with Michel clips. Subjects remained in a recovery room maintained at 26.6° C for 24 hrs after surgery (while they could not reliably maintain their own body temperature) and were treated with 100,000 units/kg Pfizerpen (penicillin G potassium) after 2 days (to prevent infection). Michel clips were removed 14 days after surgery.

Apparatus

Twenty-four hours after surgery, subjects received MK-801 [(5R,10S)-(+)-5-methyl-10,11-dihydro-5H-dibenzo[a,d]cyclo-hepten-5,10-imine hydrogen maleate;

Sigma-Aldrich, Inc.; 0.08 mg/kg, i.p.] or its vehicle. These doses have been shown to be effective in other paradigms (Keith & Rudy, 1990; Gallagher, 1990). After 30 min, half the subjects in each drug condition received 6 min of uncontrollable (noncontingent), intermittent tail shock. Rats were loosely restrained in Plexiglas tubes (22 [length] x 6.8 [internal diameter] cm) with 5.5-cm wide platforms inside (lying 5.3 cm from the top of the tube), Plexiglas covering the rostral end of the tube, and holes drilled for ventilation. A 660-V AC transformer and 2.03-Mohm series resistor together delivered a constant-current shock to the tail through cutaneous shock electrodes constructed from modified fuse clips, lightly coated with electrode paste and attached with adhesive tape 15 cm from the base of the subject's tail (for additional details, see Crown et al., 2002).

Because the spinal cord was injured, neural transmission to the brain was disrupted. This minimized the degree to which subjects "experienced" pain during stimulation. The remaining rats were treated the in the same manner but with the series disconnected so that they did not receive shock.

Locomotor Testing

Locomotor recovery was monitored over the next 3 weeks. Hindlimb locomotor performance was evaluated with the procedure and apparatus described by Basso and colleagues (1995). Prior to surgery, subjects were acclimated to transport, handling, and the open field apparatus (a 99.1 [diameter] x 20.3 [depth] cm blue children's wading pool), 4 min/day for 3 days because rodents often remain motionless on their first introduction to an apparatus. During testing, subjects were observed in a circular plastic

observation chamber for 4 minutes by experimenters blind to the treatment condition and tested for high intra- and inter-observer reliability. Intermediate milestones of the 0–21 scoring scale used include: slight movement of one joint (1), extensive (>50%) movement of all three joints (ankle, knee, and hip) (7), occasional (1–50%) weight-supported plantar stepping without forelimb-hindlimb (FL-HL) coordination (10), and consistent (95–100%) weight-supported plantar stepping with consistent FL-HL coordination (14).

The first observation was performed 24 hours after surgery, Day 1, before drug and shock treatment. Subsequent observations occurred on Days 2, 3, 4, 5, 6, 7, 9, 11, 13, 15, 18, and 21, along with weighing.

Behavioral Testing

At the end of the 21-day locomotor testing period, subjects performed three tasks to evaluate their ability to use their hindlimbs to overcome various obstacles: the ladder walk, beam walk, and inclined plane.

Acclimation. On Days 19, 20, and 21, the subjects were set on a black wooden plank (106 [length] x 50 [width] cm) and encouraged to walk across into a black wooden box (47 [width] x 25.5 [height] x 35.5 [depth] cm), where they were left for 2 min. The rats exhibit a preference for a dark, enclosed space, so the 2 min spent in the box motivate them to walk across the plank. This was then repeated twice each day, though on the last time the rats were not left in the box but were rather removed immediately.

Ladder walk. On Day 22, the three behavioral tasks were performed. For the ladder walk, subjects were encouraged to walk across a black wooden ladder (106 [length] x 17 [width] cm, with 0.8-cm diameter rungs with 2.5-cm spaces between them, totaling 31 rungs). The number of times each leg went down through the rungs of the ladder, when the subject missed a rung, was counted by one rater on each side.

Beam walk. Then subjects walked across a wooden black beam of 106-cm length, beginning at 17.2-cm width and ending at 1.0-cm width. Periodic widths are marked on the side of the apparatus. On each side of the narrowing beam, there is a 1.8-cm step down to a 3.0-cm area where subjects may step if necessary. As the subjects walk across, the width of the beam at which they step down is recorded by one rater on each side, and this is repeated once.

Inclined plane. Subjects were then placed onto an apparatus with an angled wooden plank covered with horizontally ridged rubber, with thick padding at its bottom end. The plank was raised to an inclination of 35° , which was increased by 5° until the subject could no longer stay situated horizontally on the plank for 3 s without sliding down. Angles were measured and marked on the apparatus beforehand, and were obtained by propping the plank on a bar with several notches that would catch on a vertical bar. The test was performed with the subject facing left and then right, and the highest angle at which the rat could stay standing horizontally, facing each direction, was recorded.

Sensory Testing

Within a few days after behavioral testing, tactile reactivity was assessed by applying von Frey nylon microfilaments (Semmes-Weinstein Anesthesiometer; Stoelting Co.) to the plantar surface of the paw. Increasingly stiff filaments were applied 2 s apart until the paw was reflexively withdrawn, revealing the mechanical sensory threshold, and vocalization occurred, revealing the nociceptive sensory threshold. If one or both responses were not observed, testing was terminated at a force of 300g. Each subject was tested twice on each foot in a counterbalanced ABBA order, with test sequences spaced 2 min apart. Stimulus intensity was reported with the formula provided by Semmes-Weinstein: Intensity = $\log_{10}(10,000 \times g\text{-force})$.

Within a few days after tactile testing, nociceptive reactivity was further assessed as described by Grau and colleagues (2004). Radiant heat was applied to the tail, and the subjects' latency to exhibit both tail movement and vocalization was measured, not exceeding 8 s, in order to avoid tissue damage to the subjects' tail. Constant-current shock was also administered and was gradually increased, not exceeding 1.2 mA, until the subject responded.

Histological Analysis

Histological analyses will soon be performed on all subjects to determine the extent of the damage done to the spinal cord at the area of the contusion injury. Subjects will be deeply anesthetized (100 mg/kg of pentobarbital, i.p.) and perfused intracardially with 4% paraformaldehyde. A 1-cm segment of the spinal cord including the lesion

center will be removed and embedded in paraffin. The tissue will be sectioned coronally in 20- μ m thick sections, and every 18th, 19th, and 20th slice will be preserved for staining. Sections will be stained with cresyl violet for Nissl substance and luxol fast blue for myelin (Beattie, 1992; Behrmann, Bresnahan, Beattie, & Shah, 1992). An experimenter blind to the subject's treatment condition will make camera lucida drawings of the sections, tracing around the boundary of the section and boundaries of cystic formations and areas of dense gliosis (Basso et al., 1996). Nissl-stained areas with neurons and glia of approximately normal densities denote residual gray matter, and myelin-stained areas lacking dense gliosis and swollen fibers denote residual white matter. The images will be scanned onto a Macintosh computer and imported into CANVAS 8 (Deneba Systems Inc.), where lesion area, area of residual gray matter, area of residual white matter, and width will be measured. Percent of lesioned tissue in sections at the lesion center will be compared to that of sections 2.4 mm rostral and caudal to the lesion center. A correction factor derived from section width will be applied to control for individual differences.

RESULTS

The locomotor scores derived from the method of Basso and colleagues (1995) were transformed as recommended by Ferguson and colleagues (2004) to improve their metric properties.

Shock treatment impaired locomotor recovery (Fig. 1), and this effect appeared to be attenuated by MK-801 treatment (Fig. 2).

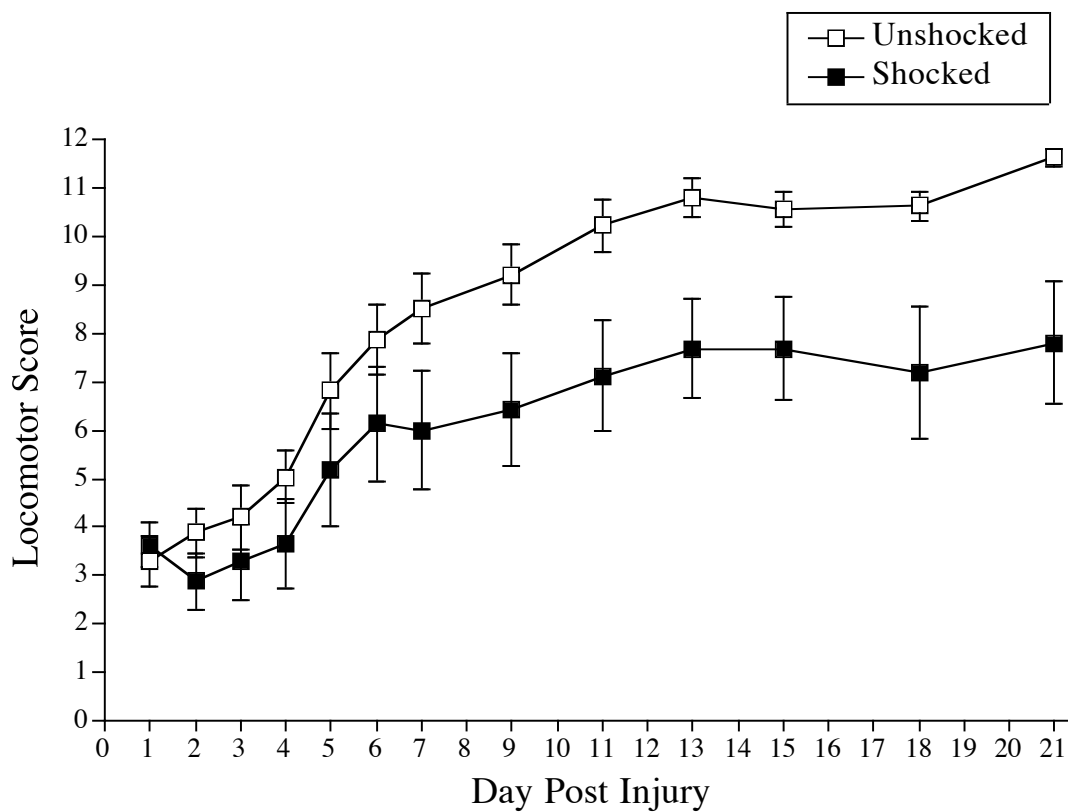


Fig. 1. Locomotor recovery in saline-treated subjects. A significant effect of shock was observed.

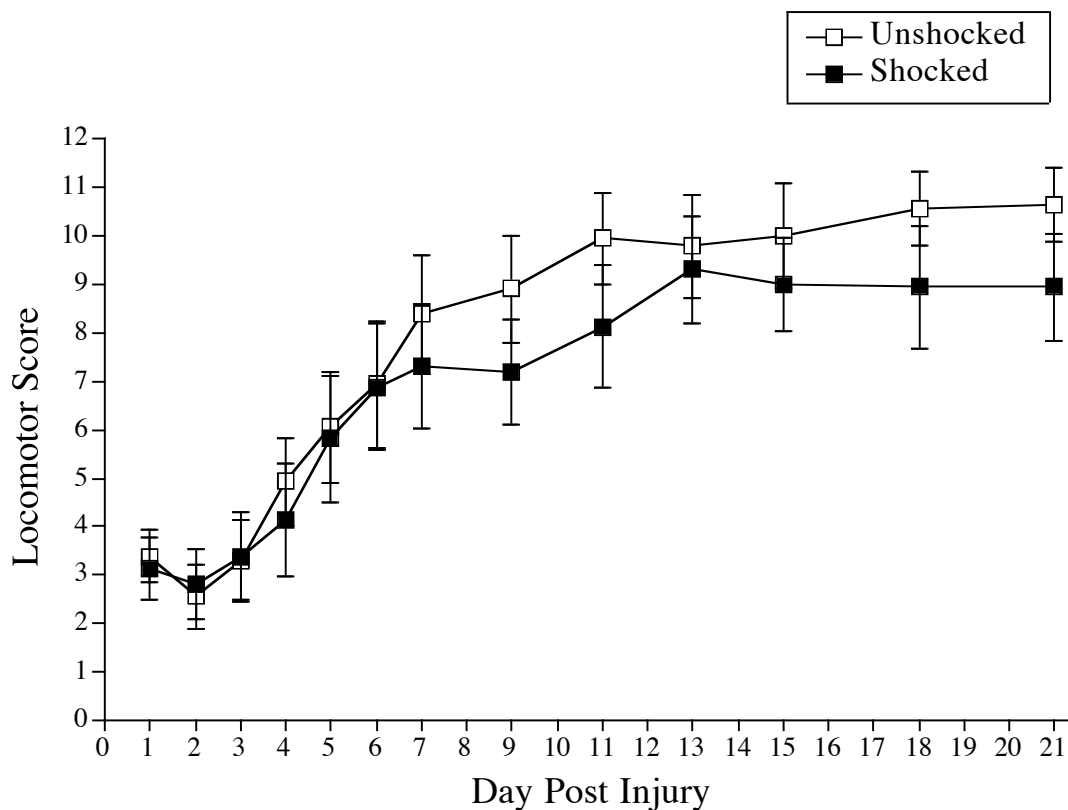


Fig. 2. Locomotor recovery in MK-801-treated rats. The deleterious effect of shock seems to be attenuated.

To control for variation in injury level across subjects, the data were analyzed using an analysis of covariance. The Day 1 score, obtained prior to shock and drug treatment, served as the covariate. As expected, this factor accounted for a large proportion of the variance, $F(1, 27) = 36.20, p < 0.0001$. There was a main effect of shock treatment, $F(1, 27) = 6.93, p < 0.05$. The shock x drug interaction approached significance, $F(1, 27) = 3.07, p < 0.091$. There was also a significant effect of recovery day, and day x shock treatment interaction, both $F_s > 3.14, p < 0.0005$. No other term approached significance, all $F_s < 1.0$. Planned comparisons revealed that shock had a

significant effect on recovery in the saline-treated ($p < 0.005$) but not the MK-801-treated rats ($p > 0.05$).

Close inspection of the data from the unshocked controls suggested that MK-801 treatment, per se, had an adverse effect on locomotor performance. This was especially evident 24 hrs after drug treatment (Fig. 3), $F(1, 13) = 5.65, p < 0.05$.

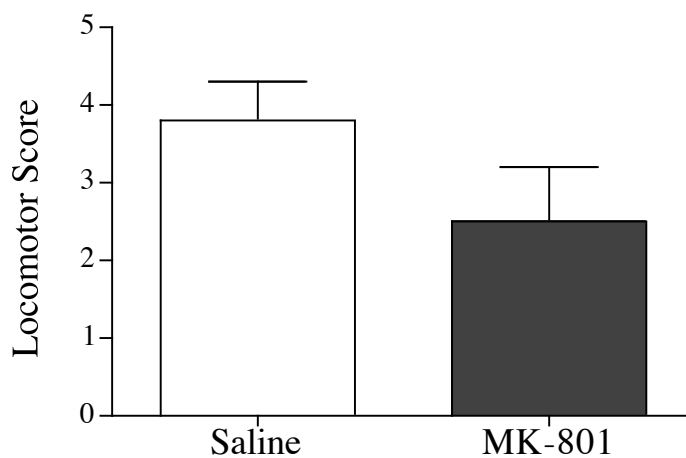


Fig. 3. Average Day 2 locomotor performance. The administration of MK-801 was detrimental to locomotor performance the next day.

MK-801 appeared to have an adverse effect on the recovery of bladder function (Fig. 4), but this effect did not reach statistical significance, $F(1, 27) = 1.20, p > 0.05$.

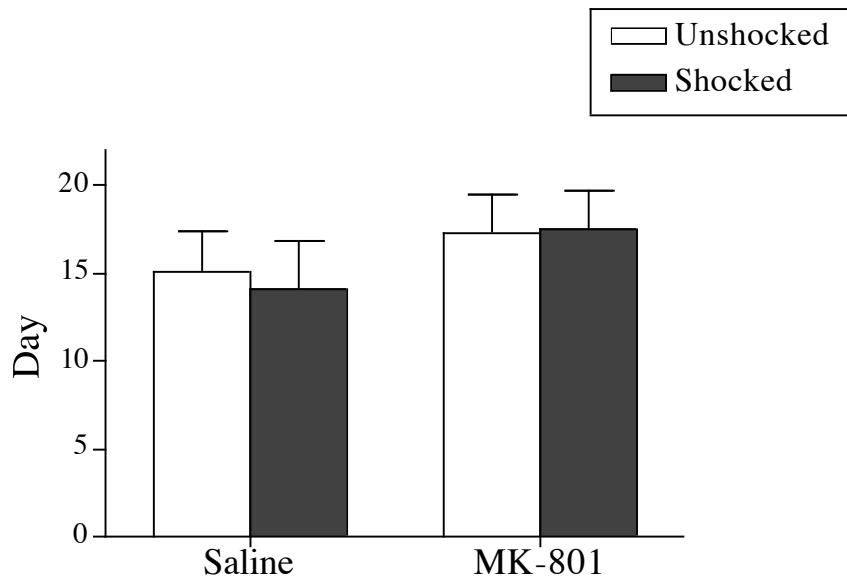


Fig. 4. Average day of recover of bladder function. MK-801 seemed to adversely affect recovery of bladder function, though the effect was not significant.

As in prior studies, shock treatment also disrupted recovery of weight after injury (Fig. 5), and this effect appeared to be attenuated by drug treatment (Fig. 6). The interaction between shock and drug treatment was marginally significant, $F(1, 28) = 3.74, p < 0.06$). There was also a significant effect of recovery day, $F(12, 336) = 36.71, p < 0.0001$.

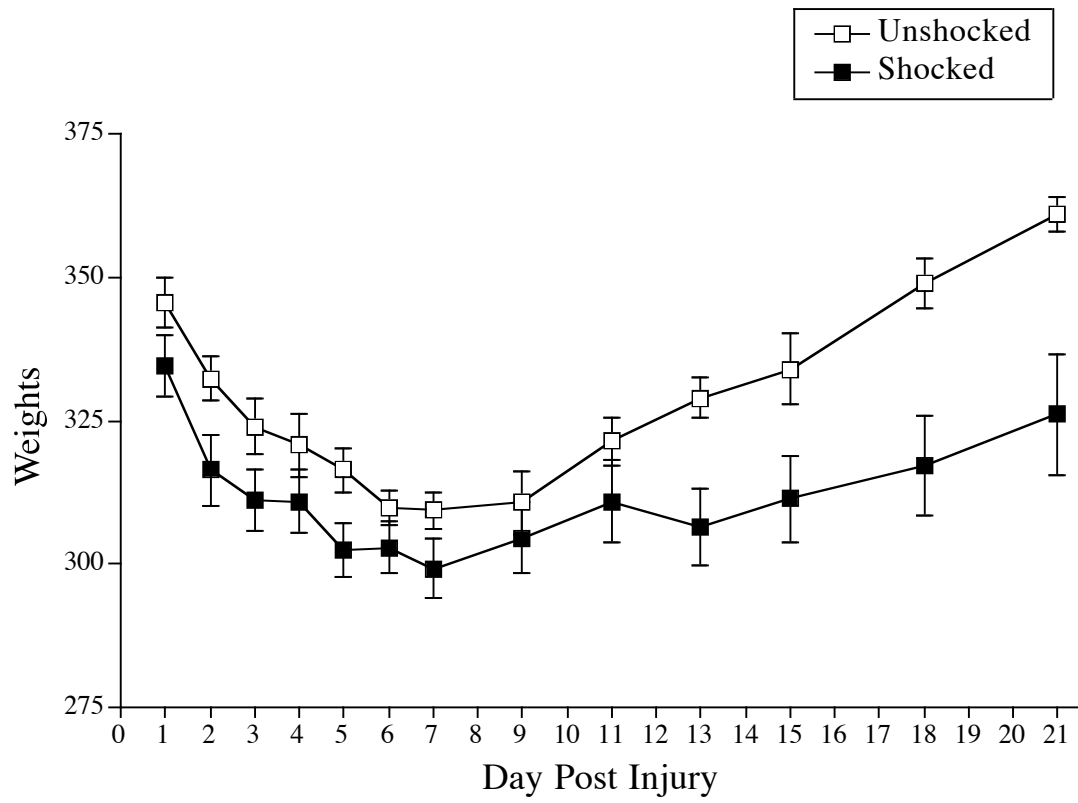


Fig. 5. Weight recovery in saline-treated subjects. Shock treatment disrupted the recovery of weight.

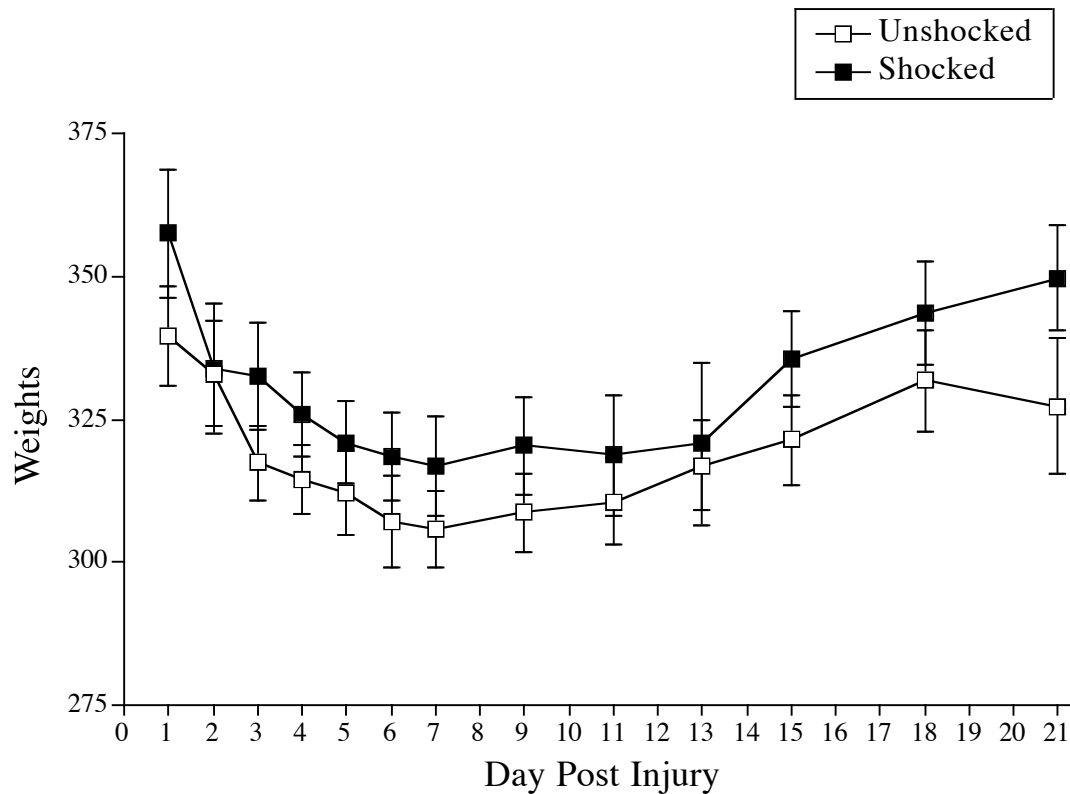


Fig. 6. Weight recovery in MK-801-treated subjects. MK-801 appeared to attenuate the effect of shock on weight, though the drug x shock interaction was only marginally significant.

The ladder walk behavioral test showed a marginally significant interaction of drug and shock treatments, $F(1, 27) = 3.79, p < 0.063$). The unshocked saline rats and shocked MK-801 rats seemed to perform better than the shocked saline rats and the unshocked MK-801 rats. It may seem paradoxical to call their performance better if they stuck their legs through the rungs a greater number of times. However, at these rats' level of performance, very low ladder scores indicate that their legs were being held stationary above the rungs. Higher scores in general characterize rats that were at least

attempting to use their legs. The implications of the scores would be reversed with higher-performing rats.

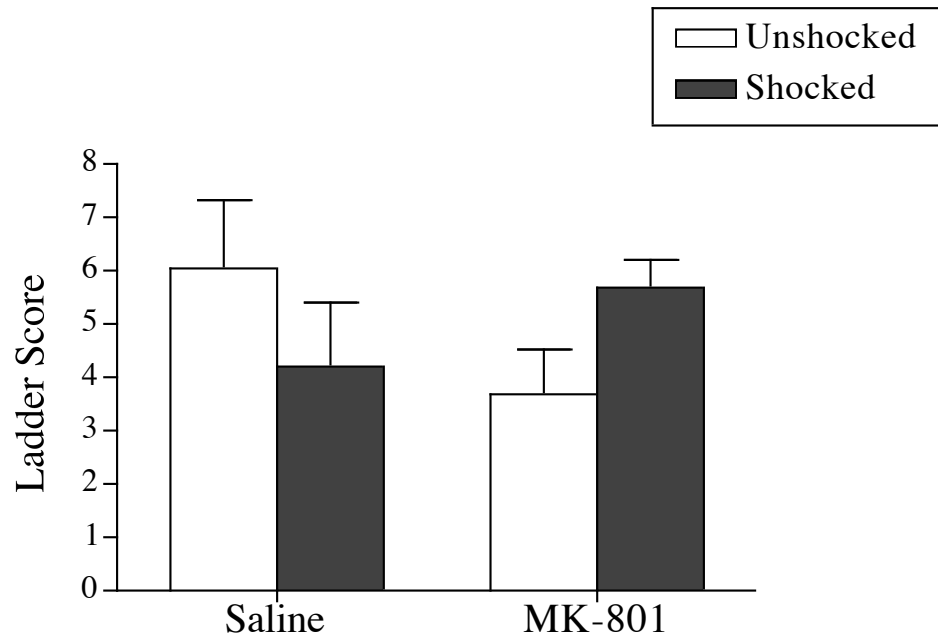


Fig. 7. Average ladder scores. MK-801 appeared to improve ladder scores in shocked rats and worsen them in unshocked rats.

The other behavioral tests, the beam and the inclined plane, showed no significant differences between groups (all $F_s < 1.884$). Tests of tactile and nociceptive reactivity also showed no significant differences between groups (all $F_s < 2.005$).

DISCUSSION

Conclusions

As reported in past studies (Grau et al., 2004), the significant effect of shock treatment indicates that uncontrollable stimulation impairs recovery after spinal cord injury. My results suggest that the adverse effect of uncontrollable stimulation can be attenuated by the NMDA receptor antagonist MK-801.

Unexpectedly, MK-801 alone can adversely affect locomotor performance after the drug has cleared the system. This effect was especially evident in the Day 2 scores, which dipped for shocked groups and MK-801 groups, but not for the unshocked saline group. MK-801 groups also seemed to be impaired in regaining bladder function. However, MK-801 seemed to protect rats from the adverse effects of shock on weight gain, though this effect was only marginally significant and was obscured by the difference in initial weight across groups.

Further Inquiry

I am now examining a lower dose of MK-801, 0.02 mg/kg, to determine if it may have a protective effect from uncontrollable stimulation without causing damage per se. Preliminary results are promising, as this dose does not cause a dip in Day 2 scores in unshocked subjects.

Implications

A precise statement about the clinical significance of MK-801 in improving the long-term outcome of spinal cord injury cannot be made yet. There is evidence that MK-

801 protects the contused spinal cord from the adverse effects of uncontrollable stimulation, but it is important to discern that there is a dose of MK-801 that has this protective effect without its own adverse effect.

This study fits within an array of experiments with animal and human models examining the benefits of NMDA receptor antagonists in suppressing central sensitization.

Faden and Simon showed in 1988 that NMDA worsened the outcome of thoracic spinal cord injury in rats. NMDA's stereoisomer, NMLA, had no effect, and MK-801 improved the outcome. Faden, Ellison, and Noble (1990) found that the administration of the non-competitive NMDA receptor antagonist CPP or the competitive NMDA receptor antagonist dextrorphan also improved the outcome of thoracic spinal cord injury. Yum and Faden (1990) showed that MK-801 protected nervous tissue from secondary damage caused by ischemic central nervous system injury, which is injury involving blood restriction to the nervous system. Searching for factors that play a role in the adverse effects of NMDA receptors on spinal cord injury, Yanasse, Sakou, and Fukuda (1995) indicated that NMDA receptors contribute to edema formation in the early stages after spinal cord injury. They too showed that MK-801 administration after spinal cord injury significantly improved motor recovery. They found that MK-801 reduced edema formation at the site of injury but did not alter blood flow or vascular permeability. Li and Tator (2000) concurred that MK-801 did not protect the spinal cord by altering blood flow. Wada and colleagues (1999) clarified that the NMDA receptor

promotes delayed cell death of neurons and glia through apoptosis. They found that the spinal cords rats treated with MK-801 after spinal cord injury exhibited significantly less apoptosis than those of rats treated with saline after injury. Evidence against the potential of NMDA receptor antagonists came from Haghghi and colleagues (2000), who did not find a significant effect of MK-801 administration on rats given spinal cord injuries. However, Haghghi, Johnson, de Vergel, and Vergel Rivas (1996) showed that pretreatment with MK-801 improved the neurophysiological outcome of rats that received spinal cord injuries. Overall, despite somewhat mixed results in various contexts, clearly animal models have demonstrated the adverse effects of NMDA receptors on subjects given spinal cord injuries and the potential of NMDA receptor antagonists in improving the outcome of spinal cord injuries.

Other researchers have searched for more-effective NMDA receptor antagonists. The recently developed noncompetitive NMDA receptor antagonist gacyclidine has received favorable assessment (Feldblum, Arnaud, Simon, Rabin, & D'Arbigny, 2000; Gaviria et al., 2000). Yu, Marcillo, Fairbanks, Wilcox, and Yeziarski (2000) promote the use of agmatine, an NMDA receptor antagonist and nitric oxide synthase (NOS) inhibitor. NOS contributes to secondary damage after spinal cord injury. They found that agmatine significantly improved locomotor recovery and reduced tissue damage in rats given spinal cord injuries. They went on to emphasize the importance of drugs with multiple targets for treatment following spinal cord injury.

Clinical studies have provided evidence that NMDA receptor antagonists can reduce the effects of central sensitization in humans. Patients with central dysesthesia pain, which is centrally mediated burning pain, experienced less pain when treated with ketamine, another noncompetitive NMDA receptor antagonist (Eide, Stubhaug, & Stenehjem, 1995). The subjects did not experience significant side effects. Ketamine also significantly reduced post-herpetic neuralgia after intravenous administration compared to both saline and morphine (Eide, Jørum, Stubhaug, Bremnes, & Breivik, 1994).

Ketamine has also been shown to inhibit secondary hyperalgesia if given to subjects during and after surgery (Stubhaug, Breivik, Eide, Kreunen, & Foss, 1997). The kidney donors who received ketamine not only showed lower punctuate mechanical hyperalgesia measured with von Frey filaments than did donors who received placebo, but also consumed less morphine after surgery and reported higher global satisfaction. The authors attribute this to ketamine's blocking the induction of central sensitization.

Therefore, it appears that NMDA receptor antagonists already show promising results in treating neuropathic pain in humans. It is theorized that this type of pain is caused by central sensitization, which has also been implicated in causing secondary nervous system damage and poor locomotor recovery in animal models. My study incorporates the important factor of uncontrollable nociceptive stimulation, demonstrating that MK-801 can protect spinally injured rats from its adverse effects. In human spinal cord injury, uncontrollable nociceptive stimulation is often an issue

because of associated peripheral injuries. There are even clinical treatments intended to improve motor function following spinal cord injury that entail application of uncontrollable stimulation to a limb to prevent muscle atrophy. In both of these cases, the patient may not experience pain because of damaged spinal cord connections, but the stimulation could cause secondary damage to the spinal cord. An NMDA receptor antagonist could protect the patient's spinal cord from this secondary damage. This study therefore adds an important dimension to the research on the protective effects of NMDA receptor antagonists following spinal cord injury and expands their potential clinical implications. Furthermore, it illustrates the necessity to exercise caution in administering an NMDA receptor antagonist in clinical studies, because a high dose can cause secondary damage on its own.

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CURRICULUM VITAE

Christine Elizabeth Petrich

PERSONAL INFORMATION

Born September 13, 1985, in San Antonio, Texas
Married to Paul Jacob Mariano

EDUCATION

Baylor College of Medicine (accepted) Houston, Texas Expected Graduation: June 2010	Doctor of Medicine Degree
Texas A&M University College Station, Texas Expected Graduation: May 2006	Bachelor of Science Degree Major: Psychology, Minor: Classics GPR: 4.0/4.0

RESEARCH

Texas A&M University Undergraduate Research Fellows Program Class of 2006

- Thesis: *Effect of the NMDA receptor antagonist MK-801 on recovery from spinal cord injury in rats given uncontrollable stimulation*
- Collaborate with faculty advisor on research project
- Petrich, C. E., & Grau, J. W. (2006, March). *Effect of the NMDA receptor antagonist MK-801 on recovery from spinal cord injury in rats given uncontrollable stimulation*. Poster presented at Student Research Week, College Station, TX.

Dr. James Grau's Neuroscience Laboratory, Texas A&M University

- Currently performing research for publishable-quality paper
- Undergraduate research assistant from September 2004 to present
- Conduct lab work for research projects on spinal cord learning and recovery from spinal cord injury in rats
- Skills: Rat spinal contusion, rat spinal transection, BBB hindlimb locomotion scoring, rat intraperitoneal injection, rat bladder expression, microtome use

LEADERSHIP

2006 Aggieland Yearbook, Texas A&M University

- Academics Editor (Fall 2005–Spring 2006)
- Implement the assembly of the academics section of the yearbook by choosing topics to cover, ordering stories and photos, and placing elements onto designed pages

2005 Aggieland Yearbook, Texas A&M University

- Copy Editor (Fall 2004–Summer 2005)

- Direct the completion of requested stories by presiding over writers' meetings, assigning stories to writers, writing stories not taken by writers or by the associate copy editor, editing stories for style and content, altering story length as necessary, and collaborating with the associate copy editor at many levels of management

2004 Aggieland Yearbook, Texas A&M University

- Associate Copy Editor (Spring 2004–Summer 2004)
- Assist the copy editor by assigning stories to writers, writing stories not taken by writers or by the copy editor, editing stories, and altering story length.

HONORS

- Phi Beta Kappa Society Member (2006)
- Sigma Xi Scientific Research Society Associate Member (2006)
- Golden Key International Honour Society Member (2005)
- Phi Kappa Phi Honor Society Member (2004)
- Psi Chi Psychology Honor Society Member (2004)
- College of Liberal Arts Dean's List (Fall 2003–Fall 2005)
- National Merit Scholar (2003)
- Galen T. Brown Scholar (2003)
- Texas A&M University President's Endowed Scholar (2003)
- Texas A&M University Merit Plus Scholar (2003)
- Edward Herman Gohmert Memorial Scholar (2003)
- National Latin Exam Scholar (2003)
- Alamo Heights Optimist Club Scholar (2003)
- Thrivent Scholar (2003)