JOURNAL OF APPLIED BEHAVIOR ANALYSIS 1997, **30,** 105–120 NUMBER 1 (SPRING 1997)

DIRECT AND COLLATERAL EFFECTS OF RESTRAINTS AND RESTRAINT FADING

WAYNE W. FISHER, CATHLEEN C. PIAZZA, LYNN G. BOWMAN, GREGORY P. HANLEY, AND JOHN D. ADELINIS

KENNEDY KRIEGER INSTITUTE AND
JOHNS HOPKINS UNIVERSITY SCHOOL OF MEDICINE

Mechanical restraints are commonly used to reduce the risks associated with severe self-injurious behavior (SIB), but may result in movement restriction and adverse side effects (e.g., bone demineralization). Restraint fading may provide a method for decreasing SIB while increasing movement and reducing these side effects. In the current investigation, rigid arm sleeves and restraint fading (gradually reducing the rigidity of the sleeves) were used with 3 clients who engaged in hand-to-head SIB. Restraints and fading reduced the hand-to-head SIB of all clients. However, for 1 client, the addition of a water mist procedure further reduced SIB to near-zero levels. For a 2nd client, another form of SIB developed that was not prevented by the rigid sleeves. For a 3rd client, a topography of SIB that was not physically prevented by the rigid sleeves was also reduced when restraints and fading were introduced.

DESCRIPTORS: developmental disabilities, self-injurious behavior, restraint fading, stimulus control

Mechanical restraints are commonly used to lessen the risk of physical injury associated with self-injurious behavior (SIB) (Paul & Romanczyk, 1973). Although often effective in preventing injury, mechanical restraints generally restrict the individual's freedom of movement, which may produce side effects such as bone demineralization, shortening of tendons, and arrested motor development secondary to disuse of limbs (Lovaas & Simmons, 1969). In addition, mechanical restraints can function as positive reinforcement for SIB (Favell, McGimsey, & Jones, 1978; Favell, McGimsey, Jones, & Cannon, 1981). Thus, devices designed to prevent SIB may, at times, increase the future probability of this response. Finally, mechanical restraints may limit an individual's ability to participate in and benefit from therapeutic services and may adversely affect an individual's social acceptability (Rojahn, Schroeder, & Mulick, 1980).

Restraint fading may be one method of mitigating potential adverse side effects while maximizing the benefits of mechanical restraints. Initially, mechanical restraints are worn throughout the individual's waking hours independent of SIB (i.e., noncontingently). SIB is prevented by the physical properties of the device (e.g., rigid arm sleeves prevent hand-to-head SIB by keeping the individual's arm straight). Subsequently, the physical properties of the devices are gradually changed to allow increased movement. If restraint fading is successful, SIB remains low during the final phases of restraint fading, even though the device no longer physically prevents the response (i.e., SIB is under stimulus control).

One benefit of restraint fading is that physical problems associated with immobility (e.g., muscle atrophy) may be less likely because the period of immobility is limited. A second potential benefit is that the phys-

This investigation was supported in part by Grant MCJ249149-02 from the Maternal and Child Health Service of the U.S. Department of Health and Human Services.

Requests for reprints should be sent to Wayne W. Fisher, Neurobehavioral Unit, The Kennedy Krieger Institute, 707 N. Broadway, Baltimore, Maryland 21205.

ical characteristics of mechanical restraints may be changed in ways that make them more socially acceptable during fading (i.e., made to look more like clothing). Finally, because the devices are applied noncontingently during restraint fading, there is little chance that contingent application of restraints will function as reinforcement for SIB.

Pace, Iwata, Edwards, and McCosh (1986) demonstrated the use of restraint fading with 2 clients who engaged in self-restraint. For 1 client, restraint fading was combined with a prompt to remove the restraints and reinforcement for restraint removal. The restraint fading procedure consisted of gradually reducing the length of rigid arm tubes, which the client held in place on his arms, from 47 cm to 5 cm. The shortened tubes then were replaced with tennis wrist bands. For a 2nd client, pneumatic air splints were used to prevent ear scratching. When fully inflated, the air splints prevented SIB. The pressure in the splints was gradually reduced from 30 mm/Hg to 2 mm/Hg. In both cases, the primary target behavior was self-restraint, which was eliminated, while low rates of SIB were maintained.

Although restraint fading has been demonstrated to be a clinically useful method for reducing self-restraint (Lerman, Iwata, Smith, & Vollmer, 1994; Pace et al., 1986), restraints and restraint fading have been used less frequently as treatment for SIB in the absence of self-restraint. Ball, Campbell, and Barkemeyer (1980) applied air splints to reduce the chronic finger sucking of a profoundly mentally retarded woman. Finger sucking was decreased initially; however, as the pressure of the air splints was reduced, finger sucking increased. The addition of a differential-reinforcement-of-other-behavior (DRO) schedule resulted in the maintenance of low rates of SIB as the pressure of the air splints was reduced.

Pneumatic air splints prevent a common form of SIB (head hitting) and have the advantage of being easy to regulate (i.e., the amount of air pressure in the splints can be systematically reduced during fading). However, one limitation of these devices is that the splints may develop leaks and frequently need to be checked and replaced (Pace et al., 1986). One purpose of the current investigation was to evaluate the effectiveness of an alternative restraint device that was specifically designed for restraint fading with individuals who display hand-to-head SIB (e.g., head punching, eye poking). A second purpose was to demonstrate that stimulus control of SIB occurred subsequent to, but not prior to, restraint fading. A third purpose was to examine the effects of the rigid arm sleeves and restraint fading on topographies of SIB that were physically prevented by the devices (i.e., hand-to-head SIB) and topographies that were not physically prevented by the devices (e.g., head banging).

METHOD

Subjects

Three individuals with severe SIB were admitted to an inpatient unit specializing in the treatment of destructive behavior. Marty was a 20-year-old man with Down syndrome, profound mental retardation, and cataracts. His SIB included head, face, and ear punching; ear, neck, and scalp scratching; and eye poking. His SIB was described as continuous and had resulted in cauliflower ears, scars, and chronic sores on his forehead, ears, and scalp. He was admitted wearing arm restraints that prevented all arm flexion, a helmet, a face shield, ear muffs, and canvas gloves. Marty had suffered a dislocated elbow secondary to the long-term use of the arm restraints. Upon admission, the arm restraints, helmet, and gloves were replaced with canvas sleeves with stays (described below), which he wore throughout the day on the living unit. Marty was de-

pendent upon others for all of his personal care (eating, bathing, dressing, etc.). He did not use any recognizable means of expressive communication.

Matt was an 8-year-old boy who had been diagnosed with profound mental retardation, bilateral vocal cord paralysis, and subglottic stenosis. Matt's SIB consisted of hitting his head and face with his fist. His SIB had resulted in severe tissue damage in the form of bleeding and bruising to the ears, head, and hands. Prior to his hospital admission, he spent most of his day with his wrists restrained to his bed or wheelchair. Initially, Matt did not wear any restraints on the inpatient unit; however, he would periodically cause such severe tissue damage that some topographies of SIB (e.g., fist to nose) were blocked until his tissue damage had healed. Decisions to block SIB were made on a daily basis by the medical team. Criteria for blocking SIB included bleeding, swelling, and bruising. Blocking of SIB occurred on approximately 50% of the baseline days (i.e., prior to restraints and restraint fading) during Matt's inpatient admission. Blocking did not occur during the functional analysis, prefading analysis, postfading analysis, or restraint fading procedure. Matt also did not use any recognizable methods of expressive communication and was entirely dependent upon others for all of his personal care.

Art was a 7-year-old boy who had been diagnosed with profound mental retardation, gastroesophageal reflux, and spinal anomalies. Art's most frequent and severe form of SIB consisted of hitting his head and his face with his fist, but he also banged his head on hard surfaces, banged his arm against his body and objects, and kicked himself in his abdomen and face. His SIB had resulted in severe tissue damage in the form of bleeding, bruising, and scarring to his face and hands. He was admitted to the hospital wearing a protective mitt on his left hand and a rigid restraint on his right arm. Initially, Art wore these devices throughout the day in the hospital. He also did not use any recognizable methods of expressive communication and was entirely dependent upon others for all of his personal care.

Functional Analysis

The analogue conditions conducted during the functional analyses were similar to those described by Iwata, Dorsey, Slifer, Bauman, and Richman (1982/1994), and included demand, social attention, alone, and toy play. The differences between the sessions described by Iwata et al. and those of the current investigation were as follows. Marty's SIB attempts directed toward his ears were blocked by the therapist in all conditions. For Marty, an ignore condition replaced the alone condition; a therapist stood directly behind him, blocked SIB directed at his ears, and ignored all other responses. Art wore his protective mitt (left hand) and his arm restraint (right arm) during the functional analysis. Five functional analysis sessions were terminated because he met medical criteria (bleeding, swelling, and bruising). For Art, the therapist presented 30 s of social attention in the form of verbal reprimands contingent upon SIB, and other responses were ignored during social attention (Fisher, Piazza, & Chiang, 1996). A fifth condition was conducted in which he was alone in a room with toys. During the demand condition for Matt, the therapist performed personal care activities (e.g., the therapist washed Matt's face). During toy play for Matt, social attention was delivered on a continuous schedule, and SIB was ignored. The functional analyses of the 3 clients were undifferentiated, with high and variable levels of SIB occurring across conditions (data available from the authors upon request).

Restraint Fading

Due in part to the inconclusive functional analyses, mechanical restraints were em-

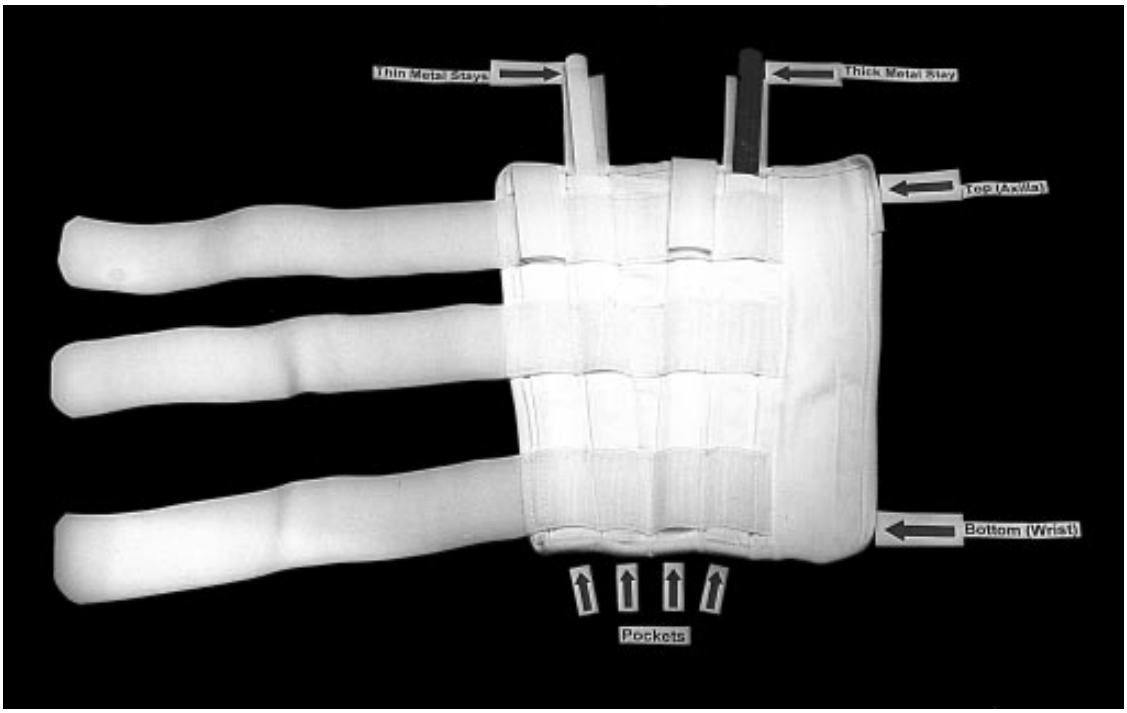

Figure 1. An example of the canvas arm sleeves used in the current investigation.

ployed to reduce SIB, and restraint fading was used to transfer control of SIB to devices that allowed greater freedom of movement. This approach was also chosen because the primary topographies for all clients involved hand-to-head SIB (e.g., eye poking, ear scratching, head punching) that frequently resulted in tissue damage and physician-ordered mechanical restraint or blocking. The restraint devices were specifically designed for restraint fading with hand-to-head SIB.

Restraint Fading Apparatus

The devices were canvas sleeves that covered the arm from the wrist to the axilla (see Figure 1). Each sleeve consisted of four pockets that could hold one thick metal stay (i.e., a total of four thick metal stays per sleeve) or up to five thin metal stays (i.e., a total of 20 thin metal stays per sleeve). The thick metal stay was the length of the sleeve and was approximately 2 mm thick. The thin metal stay was the length of the sleeve and was approximately 0.5 mm thick. The flexibility of the arm restraints was altered by changing the number or type of stays in the pockets. Light, soft stockings were placed under the sleeves to minimize skin breakdown. Our tests of these devices (with staff members) indicated that a person's arm could be flexed no more than 5° with one thick metal stay in each pocket and about 120° with no stays in the pockets. Our anecdotal observations of clients who have worn the flexible sleeves reveal that they can perform routine activities such as feeding themselves and wiping their noses without difficulty while wearing the devices.

Data Collection and Interrater Agreement

During the restraint fading analysis sessions and restraint fading plus punisher assessment sessions for Marty, observers scored SIB on laptop computers. His SIB was defined as punching any part of his head with his hand; attempting to scratch his ear, neck,

or scalp; and eye poking. During restraint fading analysis sessions for Matt, observers used laptop computers to record hand-to-head SIB (punching any part of his head with his hand) and straight-arm SIB (hitting his head with any part of his arm, but not his hand). During restraint fading analysis sessions for Art, observers used laptop computers to record hand-to-head SIB (punching any part of his head with his hand) and other SIB (banging his head against any surface, kicking any body part with his foot, and banging his arms against other body parts or surfaces).

For Marty, a 10-s partial-interval recording procedure was used, in which observers scored whether he engaged in SIB during the interval. This recording method was used because Marty's topographies of SIB were continuous (ear scratching and eye poking) as well as discrete (head and face punching). For Matt and Art, each occurrence of SIB was recorded.

The method of calculating interobserver agreement was dependent upon the type of data collection procedure. For interval measures (Marty), separate agreement percentages were calculated for occurrence and nonoccurrence on an interval-by-interval basis by dividing the number of agreements by the sum of agreements plus disagreements and multiplying by 100%. For rate (responses per minute; Matt and Art), exact agreement coefficients were calculated by partitioning each session into 10-s intervals. Agreement coefficients were calculated by dividing the number of exact agreements on the occurrence of behavior by the sum of agreements plus disagreements and multiplying by 100%.

Two observers scored SIB simultaneously but independently during 70%, 50%, and 50% of restraint fading analysis sessions for Marty, Matt, and Art, respectively, and during 12.3% of restraint fading plus punisher assessment sessions for Marty. For Marty, during the restraint fading analysis, the mean occurrence agreement for SIB was 93.3% and the mean nonoccurrence agreement was 76.8%. For restraint fading plus punisher assessment sessions, the mean occurrence agreement for SIB was 91.7% and the mean nonoccurrence agreement was 100%. Mean exact agreement for hand-to-head SIB during the restraint fading analysis was 91.9% for Matt and 94.3% for Art.

For Matt and Art, data were also collected throughout the day on the living unit using paper-and-pencil measures. For Matt, observers scored the frequency of hand-to-head SIB and straight-arm SIB during 30-min intervals. For Art, observers scored the frequency of hand-to-head SIB and other SIB during 30-min intervals. During restraint fading for Matt, interobserver agreement was not assessed for the unit data. During restraint fading for Art, exact agreement coefficients were calculated for the living unit data for each 30-min interval, as described for the restraint fading analysis sessions. Interobserver agreement was assessed during 17.6% of intervals. Mean exact agreement for hand-to-head and other SIB was 98.6%.

Restraint Fading Analysis

The general sequence of steps for the restraint fading analysis for all clients included a prefading analysis, restraint fading, and a postfading analysis.

Prefading analysis. During the prefading analysis, levels of SIB were compared during three conditions: bare arms, flexible sleeves, and rigid sleeves. The purpose of the prefading analysis, which was conducted during brief daily sessions, was to demonstrate that (a) hand-to-head SIB occurred when the client wore no restraints (bare arms condition), (b) hand-to-head SIB occurred when the clients wore restraints that did not physically prevent SIB (flexible sleeves condition), and (c) hand-to-head SIB did not occur when

the clients wore restraints that physically prevented SIB (rigid sleeves condition).

In the rigid sleeves condition, Marty wore the canvas sleeves containing one thick metal stay in each of two pockets and one thin metal stay in each of the other two pockets. Matt and Art wore the canvas sleeves containing one thick metal stay in each pocket. In this condition, the clients were unable to bend their arms at the elbow; however, they could engage in functional hand play with preferred items, and Marty could scratch his scalp when his arms were outstretched. In the flexible sleeves condition, the clients wore canvas sleeves without any stays. In this condition, the clients had full range of motion at the elbow, thus allowing them to touch, hit, or scratch their heads. In the bare arms condition, the clients did not wear sleeves.

Table 1
Number of Stays Associated With Each Fading Step

Steps	Marty	Matt	Art
Rigid sleeves			
1	2 thick, 2 thin	4 thick	4 thick
Fading (thin)			
2	20	20	20
3	17	16	16
4	14	12	12
5	12	10	10
6	10	8	8
7	8	7	7
8	7	6	6
9	6	5	5
10	5	4	4
11	3	3	3
12	1	2	2
13		1	1
Flexible sleeves			
14	0	0	0

During all sessions of the prefading analysis, the client was seated at a table next to a therapist and was provided with highly preferred stimuli that had been identified through a preference assessment (Pace, Ivancic, Edwards, Iwata, & Page, 1985) and with adult attention on a continuous schedule (attention and materials were available continuously). Stimulus presentation consisted of the therapist modeling appropriate use of the stimulus (e.g., the therapist held a fan in front of the client's face). The therapist then offered the item to the client by placing it on the table near the client's hand. However, the therapist did not otherwise prompt the client to manipulate the stimulus. The therapist manipulated each of the stimuli in a random order. The therapist also provided descriptive praise for appropriate responding (e.g., "That's nice holding the fan") and engaged in other casual conversation with the client (e.g., "It's a nice day today"). No differential consequence was delivered for SIB.

All sessions were conducted in a session room (3 m by 3 m). Session length was 5 min for Marty and 10 min for Matt and Art. Session length was short for Marty to reduce the probability that he would cause severe tissue damage during sessions because none of his topographies of SIB was blocked during the bare arms and flexible sleeves conditions. No sessions were terminated for Marty and Matt during the restraint fading analyses. For Art, nine bare arms sessions (Sessions 1, 6, 9, 10, 18, 21, 23, 27, and 29) were terminated during the prefading analysis because he met medical criteria.

Restraint fading. After the prefading analysis sessions were conducted, all clients wore the rigid sleeves during all waking hours. Fading of the mechanical restraints occurred throughout the day on the living unit. Fading was achieved by removing stays from the arm restraints (see Table 1) when rates of SIB were at or below 5% of baseline levels for 2 consecutive days for Marty and at or below 2% of baseline levels for 2 consecutive days for Matt and Art. If the criterion was exceeded at any time, the number of stays was increased to the previous step. Fading from rigid sleeves to flexible sleeves (no stays) occurred over the course of 48, 65,

and 51 days for Marty, Matt, and Art, respectively.

The conditions during fading of the mechanical restraints on the living unit were identical to those during the prefading analysis. That is, the clients were provided with highly preferred stimuli and adult attention on a nearly continuous schedule throughout the day. No differential consequences were provided for the presence or absence of SIB.

During restraint fading for Marty and Art, 10-min sessions were also conducted to provide a sample of SIB that was comparable to those in the prefading and postfading analysis sessions for each step in the restraint fading procedure. For Marty, sessions were conducted in a living area; for Art, sessions were conducted in the treatment room. For both clients, the number of stays in each sleeve during the restraint fading sessions corresponded to the number of stays worn in each sleeve throughout the day. During these sessions, the clients were provided with highly preferred stimuli and adult attention on a continuous schedule. No differential consequence was provided for SIB.

Restraint fading plus punisher assessment (Marty). For Marty, low rates of SIB occurred as the mechanical restraints were faded. However, because these rates exceeded the criterion set for fading, the effectiveness of a punishment procedure plus restraint fading was assessed. Punishment was selected for several reasons. First, continuous noncontingent access to preferred stimuli and adult attention was not effective in eliminating SIB (based on the levels of SIB during the bare arms condition). Second, Marty's SIB was extremely severe, such that a single occurrence often caused bleeding and tissue damage. Third, Marty had been exposed to a variety of reinforcement-based treatment procedures in the past, all of which had been unsuccessful. Finally, the selection of water mist as the punishment was based on input (verbal report of the acceptability of various punishment procedures) from the staff at his residential facility and consideration of his size.

During the sessions with restraint fading plus water mist, a therapist stood directly in front of Marty and briefly (1 s) activated a plant mister approximately 15 cm away from the tip of his nose each time he engaged in SIB. The mister was slanted downward to avoid spraying directly into his eyes. When the water mist procedure was added to the restraint fading procedure, the number of stays was reduced from 14 to 12 while low levels of SIB were maintained. When the water mist procedure was removed, SIB increased during sessions with restraint fading alone, and further fading was not possible. The water mist procedure was then reintroduced, and the number of stays in the restraints was decreased from 10 to 0. When we established the effectiveness of the water mist procedure during the session, water mist was used throughout the day.

Naltrexone (Matt). For Matt, the arm restraints resulted in a decrease in hand-to-head SIB during restraint fading. However, a new topography of SIB, straight-arm SIB, developed. Based on the recommendation of the medical team, a trial with naltrexone (Sandman et al., 1993) was initiated to treat straight-arm SIB. The unit data were used to evaluate the efficacy of the drug. The initial dose of naltrexone was 25 mg (1.2 mg/kg) at 8:00 a.m. for 6 days; it then was increased to 37.5 mg (1.7 mg/kg) at 8:00 a.m. for 6 days and then decreased to 0 over the course of 7 days. During the naltrexone trial, the number of stays in Matt's restraints was held constant at eight (i.e., the fading procedure was discontinued temporarily). The conditions during the naltrexone trial were identical to those during the fading analysis (access to preferred toys and adult attention, and no differential consequence for SIB).

Padded baseball cap (Matt). When the nal-

trexone trial ended due to its ineffectiveness, Matt's straight-arm SIB was treated using a padded baseball cap. The unit data were used to evaluate the efficacy of the padded cap. Matt wore the cap (a standard, adult-sized baseball cap with a 2.5 cm square piece of foam glued to the inside of the front such that the foam extended under the cap across the front portion of his head from ear to ear) throughout the day. The restraint fading procedure continued according to the criterion described above for hand-to-head SIB while he wore the padded cap. The conditions for SIB throughout the day when the padded cap was added were identical to those during restraint fading alone (i.e., preferred toys, adult attention, and no differential consequence for SIB).

Postfading analysis. When the restraints had been faded to flexible sleeves (i.e., the client had full range of motion), a postfading analysis was conducted to demonstrate that SIB occurred at high levels in the bare arms condition and at much lower levels in the flexible sleeves condition (i.e., that control of low levels of SIB was transferred from the rigid to the flexible sleeves during fading). The bare arms and flexible sleeves conditions were identical to those in the prefading analysis. The clients were given preferred stimuli and adult attention with no differential consequence for SIB (water mist was not used with Marty, and his SIB was not blocked). For Marty, session length was increased from 5 min to 10 min because he had fewer opportunities to cause tissue damage during this assessment (i.e., SIB remained low in the flexible sleeves condition). For Matt, the padded cap was not worn during postfading sessions. For Art, six sessions (Sessions 57, 58, 59, 60, 61, and 66) were terminated during the postfading reversal to the bare arms condition because he met medical criteria.

One week prior to Matt's discharge from the hospital, the number of stays in each sleeve was increased to eight, and the restraint fading procedure was reinitiated at his residential placement. This was done as a precaution to help lessen the chances of spontaneous recovery of SIB upon return to his residential placement.

For Art, rates of SIB were low during the reversal to bare arms sessions conducted in the treatment room. Therefore, 10-min sessions were also conducted in an area of the living unit in which Art played. The conditions during the sessions conducted in the playroom were identical to those during treatment room sessions. Following the reversal to the bare arms condition, we returned to the flexible sleeves condition and conducted 10-min sessions both in the treatment room and in the playroom. The reversal to bare arms and return to flexible sleeves conditions were also conducted throughout the day on the living unit.

Experimental Design

For Marty and Matt, the prefading and postfading analyses were conducted using a multielement design. The prefading analysis consisted of three conditions: bare arms, rigid sleeves, and flexible sleeves. During the postfading analysis, the bare arms and the flexible sleeves conditions were compared. The condition order was randomly selected within each phase of the assessment. For Art, a combination of multielement and reversal designs was used during the restraint fading analysis. The prefading analysis was identical to the multielement analysis used for Marty and Matt. However, when the mechanical restraints were faded to the flexible sleeves condition, a reversal was conducted to the bare arms condition (in treatment sessions and on the living unit), followed by a return to the condition with flexible sleeves (in treatment sessions and on the living unit).

During the punisher assessment sessions for Marty, an ABAB design was used. The A phase was fading of mechanical restraints

alone, and the B phase was fading of the mechanical restraints plus the water mist procedure.

For Matt, naltrexone and the padded cap were evaluated using an ABCAC design. The A phase was fading without naltrexone, the B phase was naltrexone, and the C phase was fading plus the padded cap.

RESULTS

Results of the prefading and postfading analyses for Marty are depicted in the top panel of Figure 2. Marty exhibited near-zero levels of SIB (M = 1.6%) in the rigid sleeves condition because most of his hand-to-head SIB was prevented. Marty could scratch his head with his arms outstretched, and this topography accounted for all occurrences of SIB during the rigid sleeves condition. Mean percentage of intervals of SIB was consistent and high throughout the flexible sleeves (M = 94.1%) and bare arms (M = 94.6%) conditions. Following fading (postfading analysis sessions), SIB was low during the flexible sleeves condition (M = 4.1%), but remained high during the bare arms condition (M = 98.4%). SIB was 95.6% lower in the flexible sleeves condition following fading than in the same condition prior to fading.

The bottom panel of Figure 2 depicts the percentage of intervals of SIB recorded in the 10-min sessions conducted during restraint fading (subsequent to the prefading analysis and prior to the postfading analysis). During restraint fading, the percentage of intervals of SIB remained low until the number of stays in Marty's restraints was reduced to 12 in each sleeve. After several unsuccessful attempts to decrease the rigidity of Marty's sleeves, the water mist procedure was implemented. Following the introduction of water mist, the percentage of intervals of SIB was reduced to near-zero levels. When the water mist procedure was discontinued, mean percentage of intervals of SIB increased to 8.5, which exceeded the criterion for fading the restraints. When the water mist procedure was reintroduced, mean percentage of intervals of SIB decreased to 0.7.

The top panel of Figure 3 presents rate (responses per minute) of hand-to-head SIB during the prefading and postfading analyses for Matt (straight-arm SIB did not occur during the prefading analysis and occurred three times during the postfading analysis, so data for that topography are not included). In the prefading analysis, Matt did not emit hand-to-head SIB in the rigid sleeves condition because the device prevented all hand-to-head SIB. By contrast, hand-to-head SIB was high during the flexible sleeves (M = 4.2 responses per minute) and the bare arms (M = 7.4 responses per minute) conditions. In the postfading analysis (after the restraints were faded to zero stays), Matt displayed near-zero levels of SIB in the flexible sleeves condition (M = 0.1 responses per minute) and moderately high levels in the bare arms condition (M = 4.2 responses per minute). Thus, SIB decreased in both conditions, but the decrement was much greater in the flexible sleeves condition (98%) than in the bare arms condition (43%).

The bottom panel of Figure 3 presents the rates of hand-to-head and straight-arm SIB observed throughout the day on the living unit. When Matt was not wearing arm restraints (bare arms), mean hand-to-head SIB was 3.7 responses per minute. When restraints and restraint fading were introduced throughout the day on the living unit, Matt's hand-to-head SIB remained near zero throughout the remainder of his admission. However, during restraint fading Matt developed a new topography of SIB, straight-arm SIB. Prior to the naltrexone trial, the mean rate of straight-arm SIB was 1.4. During the naltrexone trial, the mean rate of straight-arm SIB was 1.5. The introduction

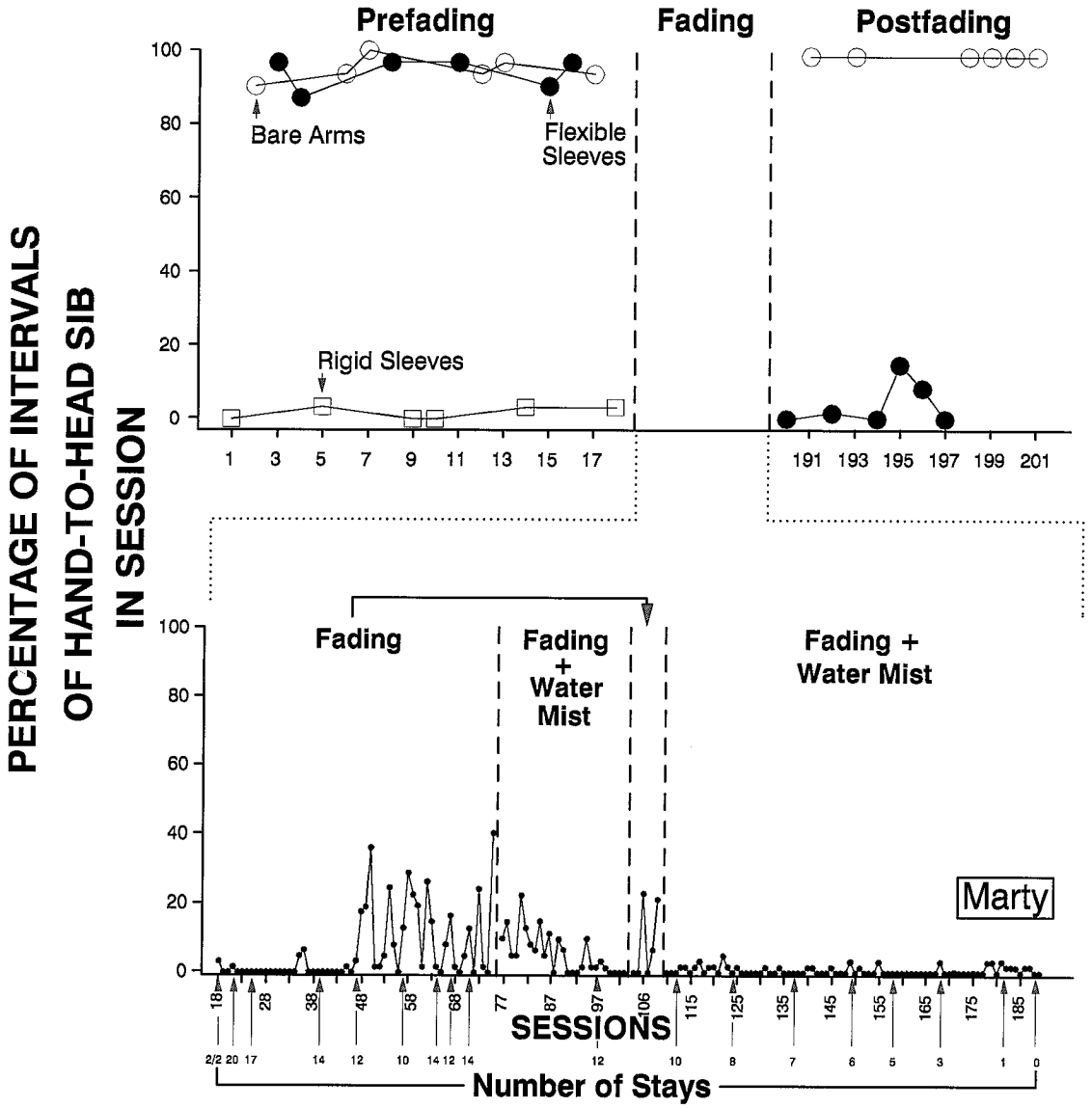

Figure 2. Percentage of intervals of SIB for Marty during the prefading and postfading analyses sessions (top panel) and during restraint fading sessions with and without the water mist procedure (bottom panel).

of the padded cap resulted in a reduction in straight-arm SIB (M = 0.4 responses per minute). When the padded cap was removed, straight-arm SIB increased (M = 0.8 responses per minute), and when the padded cap was reintroduced, straight-arm SIB decreased again (M = 0.3 responses per minute).

The top panel of Figure 4 depicts the rate of hand-to-head SIB for Art during the prefading analysis, restraint fading, and the postfading analysis. The topography of other SIB is not depicted because it rarely occurred in these sessions. In the prefading analysis, Art did not emit hand-to-head SIB in the rigid sleeves condition. SIB was highest during the bare arms condition (M = 67.7 responses per minute) and somewhat lower in the flexible sleeves condition (M = 29.4 responses per minute). During restraint fad-

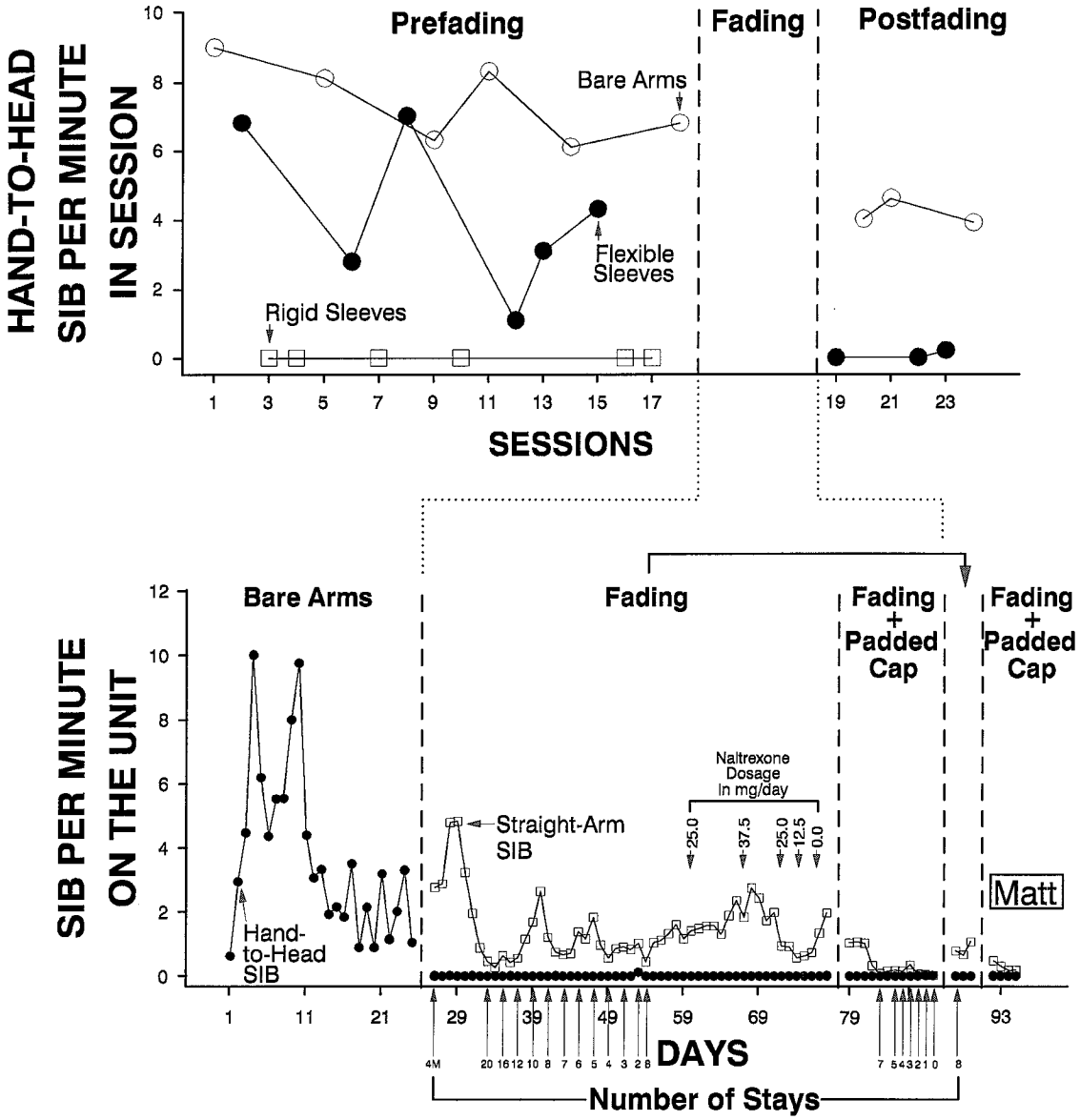

Figure 3. Rate of hand-to-head SIB for Matt during the prefading and postfading analyses sessions (top panel). Rate of hand-to-head and straight-arm SIB observed throughout the day on the living unit during restraint fading, the naltrexone trial, and the padded cap treatment (bottom panel).

ing, Art's hand-to-head SIB remained at zero during each step in the procedure. During the postfading analysis, the flexible sleeves were removed (i.e., bare arms condition). During the reversal to the bare arms condition, the mean rates of SIB in sessions conducted in the treatment room and in the playroom were 7.9 and 56.3, respectively. During the return to the flexible sleeves condition, the mean rate of hand-to-head SIB was zero in the sessions conducted in the treatment room and in the playroom.

The bottom panel of Figure 4 depicts the rates of Art's hand-to-head and other SIB throughout the day on the living unit. When Art was not wearing restraints on the unit

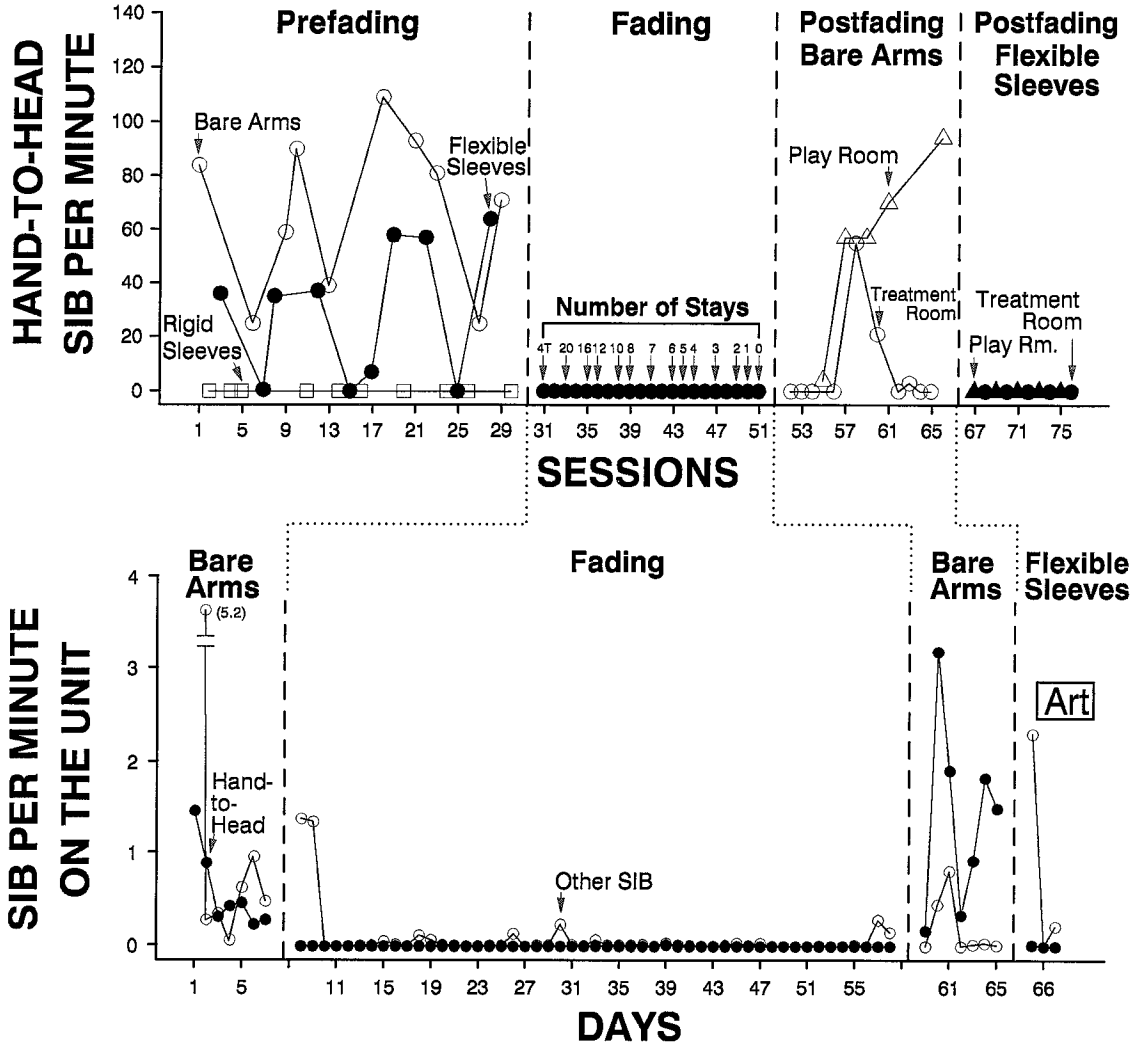

Figure 4. Rate of hand-to-head SIB for Art during the prefading analysis, restraint fading, and postfading analysis sessions (top panel). Rate of hand-to-head and other SIB observed throughout the day on the living unit during bare arms and restraint fading (bottom panel).

(bare arms), the mean rate of hand-to-head and other SIB was 0.6 and 1.2, respectively. During the 51 days of restraint fading, both hand-to-head SIB (the topography initially physically prevented by the restraints) and other SIB (the topography not affected by the restraints) were reduced to low levels. In the reversal to the bare arms condition on the living unit, the mean rate of hand-to-head SIB was 1.4 and other SIB was 0.2. During the return to the flexible sleeves condition on the living unit, mean hand-to-head SIB was 0.008 and other SIB was 0.9.

DISCUSSION

In this investigation, mechanical restraints and restraint fading were used to reduce the hand-to-head SIB (e.g., head punching, eye poking) of 3 clients with profound mental retardation who did not respond to noncontingent reinforcement (i.e., response-inde-

pendent access to preferred stimuli). Initially, the canvas arm sleeves reinforced with metal stays reduced hand-to-head SIB by preventing elbow flexion. Gradually, the rigidity of the sleeves was decreased by altering the number and thickness of the metal stays in the sleeves until the clients had full range of motion and could engage in hand-to-head SIB (i.e., the flexible sleeves condition). The low rates of SIB that occurred under the rigid sleeves condition were maintained during the flexible sleeves condition, with some exceptions. Further, SIB continued to occur at much higher levels when no sleeves were present (i.e., bare arms condition).

For Marty, as the flexibility of the restraints was increased during restraint fading, SIB also increased. Although the levels of SIB during restraint fading were much lower than those in baseline, they exceeded the criterion set for fading. We then added a water mist procedure to reduce SIB further and continued the fading procedure. Thus, in Marty's case, restraint fading superimposed on a noncontingent reinforcement condition was not sufficient to eliminate SIB. During the postfading analysis, the water mist was not used, and levels of SIB remained low in the flexible sleeves condition but not in the bare arms condition, indicating that the flexible sleeves exerted stimulus control over SIB. However, it is not clear whether (a) these low levels of SIB would have occurred if the water mist procedure had not been used previously during fading, or (b) these low levels of SIB would have been maintained over time without contingent implementation of the water mist, in that only a few sessions were conducted in the postfading analysis.

The results for Marty raise the question of whether pairing a specific stimulus with a punisher such as water mist can facilitate transfer of stimulus control during the fading process. That is, the presence of a stimulus with a history of being discriminative for punishment may help suppress SIB or other problem behavior as the stimulus is gradually faded and as the schedule of punishment is gradually changed from a fixed-ratio 1 schedule to increasingly intermittent schedules. Future research should be directed toward addressing this issue.

For Matt, the restraint fading procedure eliminated his hand-to-head SIB. However, he developed an alternative topography of SIB (straight-arm SIB) that had not occurred prior to using the restraint fading procedure. An additional treatment (a padded baseball cap) was then added to reduce his straight-arm SIB. The addition of the padded cap resulted in low levels of straight-arm SIB with no increase in hand-to-head SIB. In addition, no other topographies of SIB emerged after treatment with the padded baseball cap. Unfortunately, the analysis of the baseball cap was partially confounded by a trial of naltrexone just prior to treatment with the padded cap. The results of the padded cap assessment should also be viewed tentatively because living unit data were used to evaluate its effects, and interrater agreement was not assessed for these data.

For Art, the restraint fading procedure resulted in the expected decrease in hand-to-head SIB, the topography that was initially prevented by the sleeves. In addition, application of the sleeves resulted in a decrease in other topographies of SIB (e.g., head banging, self-kicking), even though these topographies were not physically prevented by the sleeves. However, the effects of the restraints on other SIB should be interpreted with caution because the rate of other SIB was variable and did not show a clear reversal when the restraints were removed throughout the day on the living unit.

These results replicate and extend the literature on restraint fading in several ways. First, restraint fading has been used most often with clients who exhibit SIB and self-

restraint (e.g., Pace et al., 1986), a response that is incompatible with SIB but also interferes with social interaction and learning and can cause health problems (Smith, Iwata, Vollmer, & Pace, 1992). It may be easier to maintain low levels of SIB among individuals who display self-restraint, because SIB is low prior to initiation of the restraint fading procedure. The results of the current investigation demonstrate that restraint fading can be used to maintain low levels of severe hand-to-head SIB among persons who do not display self-restraint. The restraint fading procedure eventually allowed the clients full range of motion while maintaining low levels of SIB and presumably reduced health risks associated with immobility. Second, the prefading and postfading analyses employed in this investigation provide a method for evaluating the extent to which devices that do not physically prevent SIB (e.g., flexible sleeves) exert stimulus control over the behavior before and after restraint fading with individual clients.

In general, basic operant studies have employed group comparison designs to evaluate the effects of fading (e.g., one group of pigeons receives errorless discrimination training via fading and another receives traditional discrimination training; e.g., Terrace, 1963). The experimental conditions of the current investigation were rapidly alternated during the prefading analysis, and the levels of SIB in the flexible sleeves condition were more similar to levels observed in the bare arms condition than in the rigid sleeves condition. Thus, in the prefading analysis, rapid changes from the rigid to the flexible sleeves condition did not result in a transfer of low levels of SIB. By contrast, following gradual changes in the rigidity of the sleeves (i.e., fading), the postfading analysis showed that SIB was much lower in the flexible sleeves condition than in the bare arms condition. Thus, this method demonstrated that the flexible sleeves exerted limited (Matt and Art) or no (Marty) stimulus control over SIB prior to fading, but they exerted clear stimulus control for all clients after fading.

It is possible, although unlikely, that wearing the rigid sleeves (i.e., without fading) for the period between the prefading and postfading analyses would have resulted in transfer of control of low levels of SIB, and the experimental design employed in this investigation did not control for this possibility. It is significant to note, however, that Marty wore rigid sleeves for 14 years in his residential setting prior to the prefading analysis, yet there was no apparent generalization of stimulus control to the flexible sleeves during this analysis. A multiple baseline across subjects design would have controlled for the effects of the time that elapsed during fading.

Several steps were taken to minimize the potential adverse side effects associated with mechanical restraint for the clients in the current investigation. First, the sleeves were applied noncontingently (i.e., independent of SIB), which may have reduced the probability that the restraints would acquire reinforcing properties. Second, the flexibility of the sleeves was reduced to minimize the physical risks associated with mechanical restraints (e.g., skin breakdown, shortening of tendons). Even though fading was a gradual process, it occurred relatively quickly (48, 65, and 51 days for Marty, Matt, and Art, respectively) when compared to the length of time mechanical restraints had been used with these clients prior to admission (14 years, 2 years, and 4 months, for Marty, Matt, and Art, respectively). Finally, forms of protective equipment that had been used in the past with these clients were less socially acceptable (a large brown helmet with a face guard and ear mitts, Plexiglas arm restraints, gloves, wrist cuffs attached to a wheelchair). Fading of the restraints used in the current investigation resulted in a more socially acceptable form of restraint. That is,

the flexible sleeves resembled a long-sleeved shirt and, following fading, afforded the clients full range of motion.

The sleeves used in the current investigation are well-suited for the treatment of hand-to-head SIB for a number of reasons. First, in the rigid sleeves condition (e.g., one thick metal stay per pocket), clients are typically unable to engage in hand-to-head SIB. Second, the changes in the flexibility of the sleeves can be made systematically by replacing the four thick metal stays with 20 thin metal stays (i.e., five stays per pocket) and then decreasing the number of stays in each pocket. With other forms of restraint, it is often difficult to fade the physical properties of the devices that provide protection from SIB. For example, it would be more challenging to systematically "thin" a foam helmet and ultimately switch from a foam helmet to some other type of head gear (e.g., a baseball cap) than to remove stays from canvas sleeves. Third, restraint fading is not very labor intensive, requiring only monitoring of the rates of SIB, daily skin checks, and changing the number of stays according to a schedule (e.g., once a day or once every other day). Finally, unlike pneumatic air splints, which may develop leaks, there are few practical problems with the sleeves.

REFERENCES

Ball, T. S., Campbell, R., & Barkemeyer, R. (1980). Air splints applied to control self-injurious finger sucking in profoundly retarded individuals. *Journal of Behavior Therapy and Experimental Psychiatry, 11,* 267–271.

Favell, J. E., McGimsey, J. F., & Jones, M. L. (1978). The use of physical restraint in the treatment of self-injury and as a positive reinforcer. *Journal of Applied Behavior Analysis, 11,* 225–242.

Favell, J. E., McGimsey, J. F., Jones, M. L., & Cannon, P. R. (1981). Physical restraint as positive reinforcement. *American Journal of Mental Deficiency, 85,* 425–432.

Fisher, W. W., Piazza, C. C., & Chiang, C. L. (1996). Effects of equal and unequal reinforcer duration during functional analysis. *Journal of Applied Behavior Analysis, 29,* 117–120.

Iwata, B. A., Dorsey, M. F., Slifer, K. J., Bauman, K. E., & Richman, G. S. (1994). Toward a functional analysis of self-injury. *Journal of Applied Behavior Analysis, 27,* 197–209. (Reprinted from *Analysis and Intervention in Developmental Disabilities, 2,* 3–20, 1982)

Lerman, D. C., Iwata, B. A., Smith, R. G., & Vollmer, T. R. (1994). Restraint fading and the development of alternative behaviour in the treatment of self-restraint and self-injury. *Journal of Intellectual Disability Research, 38,* 135–148.

Lovaas, O. I., & Simmons, J. Q. (1969). Manipulation of self-destruction in three retarded children. *Journal of Applied Behavior Analysis, 2,* 143–157.

Pace, G. M., Ivancic, M. T., Edwards, G. L., Iwata, B. A., & Page, T. J. (1985). Assessment of stimulus preference and reinforcer value with profoundly retarded individuals. *Journal of Applied Behavior Analysis, 18,* 249–255.

Pace, G. M., Iwata, B. A., Edwards, G. L., & McCosh, K. C. (1986). Stimulus fading and transfer in the treatment of self-restraint and self-injurious behavior. *Journal of Applied Behavior Analysis, 19,* 381–389.

Paul, H. A., & Romanczyk, R. G. (1973). Use of air splints in the treatment of self-injurious behavior. *Behavior Therapy, 4,* 320–321.

Rojahn, J., Schroeder, S. R., & Mulick, J. A. (1980). Ecological assessment of self-protective devices in three profoundly retarded adults. *Journal of Autism and Developmental Disorders, 10,* 59–66.

Sandman, C. A., Hetrick, W. P., Taylor, D. V., Barron, J. L., Touchette, P., Lott, I., Crinella, F., & Martinazzi, V. (1993). Naltrexone reduces self-injury and improves learning. *Experimental and Clinical Psychopharmacology, 1,* 242–258.

Smith, R. G., Iwata, B. A., Vollmer, T. R., & Pace, G. M. (1992). On the relationship between self-injurious behavior and self-restraint. *Journal of Applied Behavior Analysis, 25,* 433–445.

Terrace, H. S. (1963). Discrimination learning with and without errors. *Journal of the Experimental Analysis of Behavior, 6,* 1–27.

Received April 15, 1996
Initial editorial decision June 17, 1996
Final acceptance September 26, 1996
Action Editor, Brian A. Iwata

STUDY QUESTIONS

1. Describe the potential adverse side effects of mechanical restraint and how restraint fading might mitigate these.
2. What types of restraint had been used with the participants prior to admission?
3. Describe the restraint apparatus used in the study and how its flexibility could be altered.
4. How and why did response recording differ among the three individuals?
5. What conditions were in effect during the prefading analysis, and what did the data show?
6. What changes were made in the fading procedures for Matt and Marty, and what results were obtained?
7. What changes in behavior were revealed during the postfading analysis relative to the prefading analysis? Why must the results obtained for Marty be interpreted with some degree of caution?
8. What was the primary experimental design used in the study, and what other designs were embedded within it?

Questions prepared by Jana Lindberg and Julie Burke, University of Florida