The treatment of severe self-injurious behaviour by the systematic fading of restraints: Effects on self-injury, self-restraint, adaptive behaviour and behavioural correlates of affect

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ABSTRACT

Severe self-injurious behavior (SIB) in people with mental retardation is difficult to treat when dangerously frequent or intense responding rules out functional analysis and interventions that permit free responding. This situation is common when restrictive devices, such as straight arm splints, are used. In this study, the effects of introducing flexion into a straight-arm splint, on SIB, self-restraint, adaptive behavior, and behavioral correlates of affect were examined for three individuals with severe mental retardation. Using single-case design methodology, for two individuals self-injury was reduced to zero, while the overall level of restriction was also significantly reduced. From the observed behavioral correlates of affect, there was no evidence of an increase in negative affect with the introduction of the new splint and the fading procedure, but there was evidence of an increase in positive vocalizations. Engagement in activities and social contact were not affected by the introduction of the new splint. The reasons for a decrease in SIB with a corresponding decrease in restriction in the absence of any manipulation of contingencies for SIB are discussed, with particular reference to stimulus control.
INTRODUCTION
The prevalence of self-injurious behavior (SIB) in persons with mental retardation lies between 4% and 14% and the most common forms are skin picking and scratching, biting and head-banging and punching (Griffin et al., 1987; Oliver, Murphy, & Corbett, 1987; Rojahn, 1986; Schroeder, Schroeder, Smith and Dalldorf, 1978). A number of studies have documented the variability in severity of self-injury within cohorts, with the extent of the resultant injury varying from mild abrasions to extensive scarring. While indices of severity differ, a high frequency of SIB and the use of protective devices or restraints are commonly cited as likely to reflect severe SIB (Griffin et al., 1987; Oliver et al., 1987). Oliver et al. (1987) reported that, in a total population sample, 20% of individuals who self-injured to the point of tissue damage in the previous 4 months, self-injured at least once an hour, while 13% wore protective or restrictive devices for at least some of the time. The most commonly used device was straight-arm splints (39% of those wearing devices). SIB of sufficient severity to warrant the use of protective devices is likely to substantially compromise an individual’s quality of life and consequently warrants intervention.

There is little doubt that the major contribution to effective interventions for SIB has come from the field of applied behavior analysis (Emerson, 1995; Gorman-Smith & Matson, 1985). Within the last 15 years, the emphasis in this field has shifted from the technology of intervention to a more analytical framework (see Reichle & Wacker, 1993; Oliver, 1995). The role of functional analysis is established in the clinical field, although the empirical evidence for its contribution to intervention efficacy is sparse (but see Carr & Durand, 1985). While the rise of functional analysis continues, it is worth noting that, for some individuals, the more valid and reliable techniques of functional analysis, particularly experimental methods, may be problematic. This situation exists because the SIB may not vary with the manipulation of establishing operations or discriminative stimuli (see Iwata, Dorsey, Slifer, Bauman, & Richman, 1982; Iwata et al., 1994) or free responding is too dangerous to allow (Mudford, Boundy, & Murray, 1995; Duker & Seys, 1996).
These inconclusive outcomes to experimental functional analysis may not be uncommon when protective devices are employed. Indeed, it is precisely the conditions that militate against experimental analysis (i.e., high rate of responding across settings with resultant injury) that are also likely to lead to the introduction of protective devices (Duquer & Seys, 1996). Under these circumstances, interventions may be more likely to involve positive punishment contingencies, given the problems associated with extinction and differential reinforcement techniques. The deployment of these interventions is the subject of debate (see Repp & Singh, 1990) and there is some evidence that they are considered less acceptable than interventions that do not employ positive punishment (Pickering & Morgan, 1985). As they continue to cause controversy, alternative interventions for high-frequency, damaging SIB that is usually controlled by devices warrant attention.

When restraints are in use, there are two strategies that are described in the empirical treatment literature which, to some extent, overcome the problems described above. These are the differential reinforcement of periods of non-SIB by the presentation of “preferred” forms of restraint and the fading of existing restraints to exploit their stimulus control properties.

The efficacy of an intervention employing restraint as a contingency for periods of no SIB rests on restraint being reinforcing. This phenomenon has been demonstrated by Favell, McGimsey, and Jones (1978); Favell, McGimsey, Jones, and Cannon (1981); Foxx and Dufrense (1984) and Smith, Lerman, and Iwata (1996). In these studies, restraint was demonstrated as a positive reinforcer through its strengthening of other responses or SIB and/or a decrease in SIB. While this intervention strategy is appealing, since it leads to the period without restraint increasing as well as the SIB decreasing, it is not without drawbacks. First, restraint may not always be preferred and this requires prior assessment. Second, during the period in which restraints are withheld, which essentially constitutes extinction, if SIB occurs and extinction related increases in frequency and intensity of responding ensue, then if restraint is presented there is the potential for differential reinforcement for high-frequency, high-intensity responding over the long term. Third, while restraint is withheld, self-restraint may occur and this may become established if it is reinforced by the contingent presentation of restraints and/or in the same way that imposed restraint is reinforced (see Fisher & Iwata, 1996, for a
discussion of this issue). This approach may be beneficial if the self-restraint is less restrictive than the protective devices, however, if it is more restrictive, for example, wrapping in clothing, it may be more difficult to modify subsequently. Finally, while restraint is withheld, there are a number of reports of extreme distress. Responses indicative of distress appear in descriptive case studies of individuals who have Lesch-Nyhan syndrome and show severe SIB (Anderson, Dancis, & Alpert, 1978; Ball, Datta, Rios, & Constantine, 1985; Berman, Balis & Dancis, 1969; Christie et al., 1982; Dizmang & Cheatham, 1970; Duker, 1975; Gilbert, Spellacy & Watts, 1979; Hoefnagel, 1965; Nyhan, 1968; Watts, McKernan, Brown, Andrews, & Griffiths, 1974; Wurtele, King, & Drabman, 1984). Similar reports may also be found for individuals who do not have Lesch-Nyhan syndrome but who do show severe SIB (Ball, Sibbach, Jones, Steele, & Frazier, 1975; Kinnel, 1984; Lovaas & Simmons, 1969; Myers & Diebert, 1971; Shear, Nyhan, Kirman, & Stern, 1971). These levels of distress, or at least behaviors correlated with negative affect, may be so extreme that withholding restraint is untenable.

The second strategy, of restraint fading, avoids these problems. In this procedure the existing form of restraint is gradually reduced, while SIB remains at low, stable levels (Ball, Campbell, & Barkmeyer, 1980; Bull & La Vecchie, 1978; Foxx & Defrense, 1984; Pace, Iwata, Edwards, & McCosh, 1986; Paul & Romanczyk, 1973; Rojahn, Mulick, McCoy, & Schroeder, 1978; Silverman, Watanabe, Marshall, & Baer, 1984; Wurtele et al., 1984). The most parsimonious explanation for the efficacy of this intervention is that the absence of SIB is under the stimulus control of the existing form of restraint and this stimulus control is retained by the reduced restraint (Isley, Kartsonis, McCurley, Weisz, & Roberts, 1991; Pace et al., 1986; Rojahn et al., 1978). This strategy is appealing, as SIB is maintained at low levels, restraint is minimized and the resources required for implementation are minimal. The strategy is not, however, free from problems. The initial form of restraint must have the facility for appropriate modification to allow fading on the identified parameter(s) of stimulus control. While physical contact from a splint may be reduced in size with ease, it is more difficult to fade the physical contact from trapping the arms between the body and a wall or the floor. Second, as fading proceeds, alternative forms of self-restraint may appear or increase (Rojahn et al., 1978) and, consequently, the overall level of restriction may not be reduced. Third, an effective splint may be physically reduced in size by being cut in the fading process. However, if stimulus control is lost following the reduction,
it requires a new splint to be made to regain control. In the meantime, high-frequency SIB may occur and new forms of self-restraint may become established.

One potential solution to these problems is to introduce a splint that exerts an increased level of restraint over existing form of restraint (thus replacing it and acquiring the assumed functional property of existing restraints, see Rojahn et al., 1978), which has an inherent capacity for reversible fading along more than one parameter. The strategy was adopted by Ball and colleagues (1985) and Pace and colleagues (1986), who employed an air splint. However, the design of this splint only permitted fading on the parameter of flexion. The splint adopted in the present study has the same facility for introducing flexion as the air splint, but it also has a modular design, thus allowing fading in size.

In this study, a splint with design features that promote fading of restriction is evaluated for the treatment of severe SIB. The aim of the intervention is to reduce the degree of restriction experienced by participants, while SIB remains at baseline levels or is decreased. Consequently, the level of SIB is considered alongside an index of overall restriction (see Duker & Seys, 1996). As behaviors correlated with distress or negative affect are reported when restraint is decreased (see above) and when aversive contingencies are introduced (see participants E., M., Wi., We. and J. reported by Duker & Seys, 1996), levels of positive and negative vocalizations will also be assessed as an outcome variable. Finally, as levels of adaptive behavior have been reported to decrease when the form of restraint is modified (Rojahn et al., 1978) engagement and social contact will also be monitored.

STUDY 1
Method
Participant. Dawn was a 25-year-old woman with profound mental retardation caused by rubella embryopathy. Both her hearing and sight were significantly impaired, although she was fully mobile. She lived in a large hostel and attended a day-care center. She self-injured by punching the temples of her head and, less frequently, her body. While at the center she had chosen to wear a large, flat, plastic object on the lower part of each arm. These were approximately 45 cm X 20 cm x 1 cm, with hand holes at each end. She put her hands through the holes and then held the
object under her arm, thus restricting any movement of either arm. She also trapped her hands and arms and wrapped her arms in her clothing. If these restraints were removed, she showed signs of distress and attempted to retrieve them. Previous unsuccessful interventions have included reinforcement for periods of no SIB with restraint and restraint fading (see Murphy et al., 1993). A functional analysis involving free responding was untenable because of the level of distress and the frequency of head-punching.

*Design and properties of the splint.* The splint employed for the intervention was the Prime™ Motion Modular Elbow System made by Orthomerica Products Inc. This splint system is used for limiting postsurgical or post-injury arm motion and rotation. Movement at the elbow is restricted by setting the range of free flexion at predetermined intervals of approximately 30°, by moving two screws at the elbow joint. Measurement of the degree of flexion available revealed that full range of movement was apparent when 120° flexion was introduced. For measurement of the independent variable of flexion, therefore, this setting was designated full or 100% flexion. The 30° intervals between this setting and zero flexion (essentially a rigid splint) were then measured as a percentage of full flexion. Thus, using this splint, increasing the range of free flexion would allow the degree of restraint to be systematically and easily reduced. The system is also modular, thus enabling individual fitting and matching to previous forms of restraint and systematic fading in size, as components can be replaced by smaller components. Also, once components are cut to reduce the size of the splint, then if it is necessary to reintroduce the previous level of restraint, an uncut component can replace the cut component.

*Direct observation sessions: recording technique response definitions and inter-observer reliability.* Observers collected data on response frequency and duration using an Olivetti Quaderno PC. The software (Repp, Harman, Felce, Van Acker, & Karsh, 1989) allows up to 43 separate behaviors to be simultaneously recorded in continuous time and thus avoids any form of time sampling. Participant responses were as follows: Head and body punching (defined as any hard contact between a closed fist and the head or body), trapping arms (defined as either arm being pinned between the body and a stationary object), trapping hands (defined as either or both hands being inserted into a confined space such that the hand is encircled), wrapping
(defined as clothing being arranged such that either or both arms or hands were encircled by material or held against the body by material), positive vocalization (any smiling or laughing), negative vocalization (any crying, screaming, or moaning), engagement (any active manipulation of objects in a nonstereotyped way), and social contact (any directed verbal or physical contact from staff).

During approximately 15% of the sessions, an independent observer also collected data. Agreement was calculated on a 10-second interval basis using the formula for Kappa (Cohen, 1960). The levels of agreement were: head and body punching, 0.88; trapping arms, 0.74; trapping hands, 0.63; wrapping, 0.80; negative vocalizations, 0.56; positive vocalizations, 0.62; engagement, 0.71; and social contact, 0.60. The direct observational data were analyzed using Obswin software (Martin, Oliver, & Hall, 1996).

Direct observation sessions: calculation of the restriction index. To monitor the amount of restriction experienced by Dawn as a result of her previous restraints, the new splint, and the various forms of self-restraint, a restriction index was calculated. This was determined by weighting parameters of restraint, assessing the percentage of time for which a given parameter of restraint occurred, and dividing by the number of parameters of restraint to normalize across participants. For Dawn this calculation was applied to the length of time wearing the previous restraints or new splints; the length of time spent trapping arms, hands, or wrapping in clothing; and the flexion in the new splint (weighted by the percentage of flexion). The result of this calculation was then expressed as a ratio to the maximum possible. Thus, 1 would indicate constant restriction on all parameters and 0% flexion, conversely 0 would represent the constant absence of any restriction and devices associated with restriction. For example, in an observation session, if Dawn was observed to be wearing both splints all the time at 50% flexion, trapping her arms for 25% of the time but no other forms of restraint were observed, then the restriction index for that session would be: \((100 + (100 \times 0.5) + 25 + 0 + 0) \div 500 = 0.35\).

Staff observations: recording technique response definitions and interobserver reliability. Observations were conducted throughout the time that Dawn was at
the center using a momentary time-sampling procedure. Staff wore a timer that sounded at 12-minute intervals. When the timer sounded, staff observed Dawn momentarily and then recorded the presence of punching, self-restraint (i.e., wrapping, trapping arms, trapping hands), and negative and positive vocalizations. The definitions employed were those given above. To assess interobserver reliability, the staff who conducted the observations viewed a videotape of Dawn in the same setting and under the same conditions that the live observations occurred. At intervals they were required to momentarily observe the video and then record the presence or absence of the defined behaviors. The Kappa values for interobserver reliability were: arm trapping, 0.48; negative vocalizations, 0.64; positive vocalizations, 0.82; punching, 0.66; and wrapping, 0.66.

Procedure
The first evaluation of the intervention was conducted in direct observation sessions in experimental and generalization phases. In addition, observations were conducted by day-care staff throughout the day, during a baseline period, and while flexion in the splint was increased, until the maximum flexion of the splint was achieved. The decision to increase or decrease flexion was taken after considering the observed levels of SIB, self-restraint, negative and positive vocalizations, and after discussions with care staff.

Direct observation sessions: experimental phase. During the experimental phase, five brief trials of the splint were conducted, followed by a final series of two extended trials. Each trial was conducted on a separate day. In each of the five brief trials, a withdrawal design was employed to examine the effect of Dawn’s existing form of restraint (condition A) in comparison to the new splint (condition B). Each condition lasted 15 minutes. In the first trial (ABA) the splint flexibility was 25%. In the second trial (ABABABA), the splint flexibility in the first B condition was 25% and was increased to 50% for the remaining B conditions. In the following three trials (ABA, ABABA, ABA), flexibility was maintained at 50%. Two extended A phase trials of 1 hour each were undertaken with splint flexibility maintained at 50%. During this experimental phase, at the times when Dawn was not in observation sessions, the existing forms of restraint were employed.
Direct observation sessions: generalization phase. Following the second extended trial, the splint was introduced into the center for all of the time Dawn attended. On two of the days following the full-time implementation of the splint, probe observations were conducted. On the first day (23 days after the full-time introduction of the splint) three, 1-hour probes were conducted. After the second, 1-hour probe, the flexibility of the splint was increased to 75%. On the second day (52 days after the full-time introduction of the splint) two, 1-hour probes were conducted. After the first-hour probe, the flexibility of the splint was increased to 100%. A 1-hour probe session was conducted as a follow-up, 17 months after the full-time introduction of the splint.

Staff observations: evaluation phases. To assess the effect of the splint and the fading procedure, staff conducted observations prior to the implementation of the splint (baseline) and in the phases when there was 50%, 75%, and 100% flexion in the splint. No data were recorded for 25% flexion, as the splint was not introduced full-time with this degree of flexion.

RESULTS
The results from the direct observation evaluation in the experimental and generalization phases are shown in Figure 1. During the brief trials that involved a series of reversal designs, it is clear that the restriction experienced by Dawn is lower when the new splint was used, as compared with her previous form of restraint. During these trials, no punching occurred when the splint was in use, although in the fourth trial, punching was observed when the previous restraints were in use. When flexion was increased in the trials from 25% to 50%, there was no evidence that overall restriction increased, that is, that other forms of restraint compensated in some way. In the generalization phase, the reduction in restriction was maintained even when the degree of flexion was increased to 75% and 100%. This low level of restriction was maintained at 17-month follow-up. No self-punching was observed when the splint was in use during generalization.

+ Figure 2 here +

During the brief trials, self-restraint occurred more with the previous restraints as compared with the splints. However, when the splint was used, Dawn still trapped her arm at levels similar
to those seen when the previous form of restraint was employed (see Figure 1). In the generalization phase, a reduction in the level of all forms of self-restraint was evident, with arm-trapping occurring at lower levels than those seen during brief trials and when the previous restraints were employed.

Data on vocalizations show that during the brief trials there were usually no negative vocalizations. However, in two sessions high levels of negative vocalizations were evident when the splint was in use, compared to two sessions in which low levels of negative vocalizations were apparent when the previous restraints were employed. Positive vocalizations were also rare but were evident when both forms of restraint were employed. During the generalization phase, both negative and positive vocalizations were observed, although positive vocalizations were higher than negative vocalizations and higher than the levels of positive vocalizations observed when either form of restraint was employed during the brief trials.

Finally, during the brief trials, both engagement and social contact were lower when the splint was employed than when the previous form of restraint was employed. However, during generalization, the mean levels of engagement and social contact increased when the splint was employed, to levels comparable to, or higher than those observed during the brief trials. Data from staff observations, which extended from the period when the previous restraints were in use to the introduction of full flexion in the splint, are shown in Figure 2. The results confirm those from the brief and extended trials and the probes shown in Figure 1. Self-punching was reduced to zero with the full-time introduction of the splint with 50% flexion, from a mean baseline level of over 4% of observations. This zero level was maintained when flexion was increased to 75% and 100%. During baseline, when the previous forms of restraint were used, self-restraint occurred at high levels. With the introduction of the splint, wrapping and trapping hands were reduced to zero and this level was maintained when an increasing degree of splint flexion was introduced. Arm trapping by Dawn was less affected by the introduction of the splint, although it did reduce with the introduction of the splint and with the increase in flexion. Vocalizations by Dawn, as observed by the care staff, showed an increase in positive vocalizations with the introduction of the splint. This increase was maintained with the introduction of flexion. Negative vocalizations decreased with 100% flexion available from the
splint. It is notable that during baseline, negative vocalization were observed twice as often as positive vocalizations, while when the splint was in use at 100% flexion, positive vocalizations were observed 10 times as often as negative vocalizations.

+++++++ Figure 2 here ++++++++ 

DISCUSSION
From the data presented in Figures 1 and 2, it is evident that level of self-injury shown by Dawn was reduced, even though degree of restriction experienced was decreased. In fact, self-punching was possible when 50% flexion was introduced, but it was not observed. Both Figures 1 and 2 demonstrate a differential effect of the introduction of the splint on the forms of self-restraint shown by Dawn. With the new device, Dawn stopped trapping her hands and wrapping them in clothing, but persisted in trapping her arms, albeit at lower levels than those seen when the previous form of restraint was used. However, even this form of self-restraint decreased over time during generalization. The reasons for this differential effect are unclear. However, the most likely reason was that wrapping decreased since the splint restricted self-restraint movements to some degree. The design of the lower cuff of the splint may account for the decrease in hand trapping. The lower cuff has a component that went around the hand between the thumb and index finger. When the previous restraints were in place, Dawn would trap her hands in such a way that pressure was exerted in the same place, consequently, the splint may have comprised an equivalent stimulus.

Overall, the data collected on vocalizations do not show an association between the introduction of the restrictive device (the splints) and negative vocalizations. This might have been expected if the splints had been experienced as aversive by Dawn. In fact, the levels of positive vocalizations during the generalization phase are higher than when the previous restraints were in use. Also, anecdotally, there was evidence that Dawn did not find the splint aversive. She would approach and hold her arm out when they were fitted and would resist their removal. These are not uncommon behaviors associated with the use of protective or restrictive devices for severe SIB (Ball et al, 1975; Dizmang & Cheatham, 1970; Duker, 1975; Foxx & Dufrense, 1984; May & Ostler, 1981; Saposnek & Watson, 1974). Overall, the splints
did not appear aversive to Dawn.

In order to examine the effect of the introduction of the splint on engagement and social contact, these behaviors were also observed. There was no decrease in either of these behaviors with the introduction of the splint, and levels were maintained during the generalization phase.

Overall the introduction of the splint yielded positive benefits in terms of the reduction of self-injury and the reduction of the restriction experienced by Dawn. In addition, there was no evidence that Dawn experienced the splint as aversive or that levels of engagement and social contact were detrimentally affected.

**STUDY 2**

Following the positive results obtained for the introduction of splints for Dawn, two further splint trials were conducted. Criteria for inclusion in the trial were that straight-arm splints were currently in use, no intervention was currently operating or planned, and the SIB was judged severe enough to warrant intervention by care-staff and professionals involved with the individual. For both individuals, a functional analysis involving free responding was considered untenable because of the high frequency of SIB, the level of distress and the potential for injury.

*Method*

*Participants.* Dean was a 32-year-old man with Down syndrome with severe mental retardation. He lived in a bungalow with up to eight other residents and at least two care-staff at any one time. He self-injured by slapping his face with his right hand and by banging his head onto hard surfaces. Because Dean’s face slapping sometimes produced extensive swelling, cuts, and bruising to his forehead and face, Dean wore a long rigid straight-arm splint on his right arm for most of the time (day and night). If Dean banged his head, his care-staff attempted to place a cushion or a polystyrene mat under his head. If this was unsuccessful, Dean was required to wear a protective “ice-hockey” helmet. If Dean continued to bang his head while wearing the helmet, medication (diazepam) was administered.

Sarah was a 29-year-old woman with severe mental retardation. She self-injured by punching
her head with a closed fist and pulling her hair. She wore straight-arm splints on both arms, which offered a severely limited degree of flexion (about 5%). One splint was usually taken off by Sarah’s care-staff so that she could drink or feed herself. Sarah frequently punched her head and pulled at her hair during these times. Sarah also spent long periods of time sitting beside a table with the table held up close to her chest and her arms trapped underneath. When Sarah was not sitting beside the table, her care-staff would sit beside her, either holding on to her arms or “blocking” any attempts at SIB. Sarah was able to hit her head while her splints were on by raising her arm and banging her head with her upper arm. This option became more likely when the splints became “loose.”

Procedure. The evaluation of the splint was conducted by direct observation sessions in the living environment of the two participants. Observation sessions typically lasted 3 hours, although this was not always possible when the participants were scheduled to engage in activities outside the living area or when they went to private areas, such as the bathroom or bedroom. Observation sessions were conducted prior to the implementation of the splint (baseline) and during each phase in which splint flexion was increased. Flexion was increased in the splint in the same way described for Dawn.

Recording technique response definitions and interobserver reliability. Observational data collection was conducted as described for Dawn in the direct observation sessions. The operational definitions for engagement, social contact, and negative and positive vocalizations were those employed for Dawn. Additional codes for Dean were head banging (defined as any hard contact between a stationary object and the head) and face slapping (defined as any hard contact between the palm of the hand and the face). Additional codes for Sarah were hair pulling (defined as clasping the fingers around strands of hair on the head and tugging downward), sitting on hands (defined as placing the hands underneath the legs while sitting down), and staff blocking (defined as care-staff placing an arm between Sarah’s arms and her face). Interobserver reliability (Kappa) was calculated in the same way as described for Dawn for the direct observations. Mean levels of interobserver reliability for each participant across behaviors were 0.74 (range 0.46–0.95) for Dean and 0.74 (range 0.56–1.00) for Sarah. Individual reliability indices for Sarah were: trapping arms, 1.00; sitting on hands, 0.85; positive vocalizations, 0.56;
negative vocalizations, 0.75; head punching, 0.56; hair pulling, not observed; and for Dean were: face slapping, 0.75; trapping arms, 0.95; positive vocalizations, 0.46; negative vocalizations, 0.81. Low levels of agreement tended to occur when behaviors were infrequent.

*Calculation of the restriction index.* The restriction indices for Dean and Sarah were calculated in a way similar to that described for Dawn. For Dean, the behaviors used in the calculation of the restriction were: the length of time wearing the existing or new splint, the length of time spent trapping his arm, the length of the splint (weighted proportionally to its total length), and the flexion in the existing or new splint (weighted by the percentage of flexion). For Sarah, the behaviors used in the calculation of the restriction index were: the length of time wearing the existing or new splints, the length of time spent trapping her arm, the length of time spent sitting on her hands, the length of time that staff blocked her SIB, and the flexion in the existing or new splints (weighted by the percentage of flexion).

**RESULTS**

The results of the observational data collection to evaluate the impact of the introduction of the splint for Dean are shown in Figure 3. When the splint is introduced with 0% flexion, there is a marginal reduction in the restriction index from baseline levels. This situation was due mainly to the reduction of arm trapping by Dean, which reduced to near zero levels. As 25% and 50% flexion are introduced, the level of the restriction index decreases. However, when 75% and 100% flexion were introduced there was an increase in arm trapping by Dean, and this contributes to the more modest reduction in the restriction index. When arm trapping decreases during the 100% flexion phase, the upper section of the splint is removed, resulting in a fall in the overall level of restriction experienced by Dean, partly because of the weighting for this item of restraint and partly because there is a decrease to near zero levels in arm trapping. The level of restriction is further decreased by cutting the lower section of the splint with no increase in arm trapping by Dean. Although the degree of restriction experienced by Dean is decreased throughout the intervention to a point at which free responding is possible, both face slapping and head banging are reduced to below baseline levels. It is notable that the general trend in the decrease in SIB occurs despite an increase in the degree of flexion introduced.
In the latter stages of the intervention, when 100% flexion in the splint was introduced and the size of the splints was reduced, the positive vocalizations shown by Dean were comparable to baseline. However, it is also notable that negative vocalizations are higher than baseline levels when 50%, 75%, and 100% flexion was introduced and when the upper cuff was removed. These levels of negative vocalizations were not maintained when the lower section was reduced and the levels of negative vocalizations reduce while positive vocalizations increase. Throughout the intervention, the levels of engagement and social contact increased slightly when the new splint was introduced, although at the end of the intervention they were at baseline levels.

The results of the observational data for Sarah are shown in Figure 4. With the introduction of the splint, there was a modest reduction in the restriction experienced by Sarah and small decreases in the restriction index were evident as the degree of flexion increased. When the splint was introduced, staff blocking and arm trapping by Sarah decrease initially but staff blocking increases in the latter stages. When flexion of 75% was eventually introduced, staff blocking was almost constant and at this point rigid splints were reintroduced. An increase in Sarah sitting on her hands was evident with the introduction of the splint and this behavior increases with the increase in flexion. However, in the later stages of the intervention when the 50% and 75% flexion are introduced the behavior falls to zero. Finally, it is notable that during baseline the forms of external and self-restraint covary negatively, but this covariation is less evident when the new splint is introduced.

With the introduction of the splint, there was a substantial reduction in hair pulling and a less marked reduction in head punching. These reductions were maintained with the introduction of 25% flexion. However, in the fifth observation of the first phase of 25% flexion, head punching was observed at a mean frequency of approximately four per minute (above mean baseline levels) and, consequently, flexion was reduced back to 0%. With further introductions of flexion, mean levels of SIB remained below baseline. However, SIB was evident in all phases when flexion
was introduced.

Positive vocalizations shown by Sarah throughout the intervention were comparable to baseline. Negative vocalizations showed a modest reduction with the introduction of the splint, which was maintained as flexion was introduced. The observational data on engagement and social contact show that engagement was reduced when the splint was introduced and did not increase with the introduction of flexion until 75% flexion was introduced. Level of social contact increased slightly with the introduction of the splint and flexion, except for the 50% flexion phase.

DISCUSSION

For both Dean and Sarah the introduction of the splint and the increase in flexion were associated with overall decreases in SIB. The reduction for Sarah was less marked than for Dawn and Dean and hair pulling and head punching were differentially affected. Interestingly, for Dean a reduction in head banging occurred, although this behavior was not controlled by the previous restraint or the new splint. For Dean, the overall reduction in SIB occurred despite a substantial decrease in the restriction he experienced. It is notable that his form of self-restraint increased when flexion reached 50% and 75%, but this eventually decreased when the upper section was removed. The overall effect of the intervention, therefore, was similar to that observed for Dawn.

For Sarah, the initial reduction of restriction was more modest and eventually a marked increase occurred. However self-restraint was eradicated with the introduction of the splint, even when flexion was 50% and 75%, but was eventually replaced by high levels of external restraint (staff blocking). As with Dawn above, there was a differential change in self-restraint when the splint was introduced. Arm trapping immediately reduced to zero, while sitting on hands remained in her repertoire before eventually decreasing to zero. The negative covariation in forms of external and self-restraint during the baseline phase, suggest that these forms of restraint were equivalent and that self-restraint, by implication, was reinforced by the absence of SIB (see Fisher, Grace, & Murphy, 1996; Fisher & Iwata, 1996). These data, in combination with the increase in staff blocking, suggest that the degree of flexion introduced into the splint was too high for the splint to maintain equivalence to any form of self-restraint. Thus, stimulus control was compromised
and eventually lost. This situation may have arisen as SIB occurred when the splint was in use.

For both Dean and Sarah, there was no evidence that the introduction of the splint and flexion in the splint were generally associated with an increase in negative vocalizations, which might have indicated that the splint was aversive. Overall there was a mixed response, with Sarah showing a decrease in negative vocalizations with the introduction of the splint and positive vocalizations remaining relatively stable. Dean showed an increase in negative vocalizations during some phases of the intervention, but these phases were also associated with positive vocalizations. These results, when combined with the anecdotal observations that both participants would approach and hold out their arms for the splints, suggest that the splints were not experienced as aversive by the participants. Finally, for both participants there was no evidence that the introduction of the splint influenced the level of social contact or engagement.

**GENERAL DISCUSSION**

There was a significant reduction in SIB for two out of three participants with the introduction of the splint. This reduction was maintained following an increase of flexion in the splint and a corresponding decrease in the overall level of restriction. This finding is similar to those reported in other studies of restraint fading (Ball et al., 1980; Bull & LaVecchio, 1978; Foxx & Dufrense, 1984; Pace et al., 1986; Paul & Romanczyk, 1973; Rojahn et al., 1978; Silverman et al., 1984; Wurtele et al., 1984). While no comparison was made with an intervention that used restraint for differential reinforcement for the absence of SIB, this procedure was tried previously for Dawn (Murphy et al., 1993). The effects of this previous intervention were short-lived and the periods where restraint was absent were accompanied by extreme distress for Dawn. A second procedure employing the fading of existing restraints was attempted, but this was accompanied by an increase in self-restraint (see Murphy et al., 1993). The intervention procedure described in this study appeared to be more effective for Dawn, when the effect on SIB was combined with the assessment of restraint experienced and observable correlates of affect.

For all three participants there was no evidence that reducing restraint was accompanied by the distress that is commonly reported for restraint when removed while in use to control severe SIB (Ball et al., 1975; Lovaas & Simmons, 1969; Shear, Nyhan, & Kirman et al., 1971). For
two participants, Dawn and Dean, the overall degree of restriction experienced was reduced with the introduction of the splint and with the increase in flexion. The measurement of restriction, so frequently associated with severe SIB, is important in an intervention of this kind. This phenomenon is demonstrated by the results for Sarah. She evinced a decrease in SIB with the introduction of flexion. However, only modest reductions in the overall level of restriction as one form of restriction (staff blocking) compensated for the introduction of flexion in the splint occurred. When significant flexion was introduced, staff blocking occurred at such high levels that rigid arm splints were reintroduced.

Finally, for all three participants there was no evidence that social contact or engagement in activities was detrimentally affected by the introduction of the splint (cf. Rojahn et al., 1978). In this study, therefore, there was evidence that the introduction of the splint has substantial positive effects in addition to the reduction of self-injury for two of the three participants.

From the results of this study, it is not possible to determine whether similar reductions in SIB might have been achieved using an intervention indicated by the results of an experimental or descriptive functional analysis, now considered to be an essential prerequisite to intervention design. The typical format of these analyses necessitates free responding without protective devices (Hall & Oliver, 1992; Iwata et al., 1982; Lerman & Iwata, 1993). This approach was not possible for all three participants, due to the immediate injury that would occur during free responding. It is also not possible to deduce if similar results might have been attained with the use of positive punishment procedures. However, the positive outcomes described above and reported in previous studies indicate the intervention is beneficial.

It is interesting to consider why, for two participants, it is possible to reduce SIB while simultaneously introducing the capacity for free responding, a condition previously associated with high levels of SIB. The existing restraints clearly exerted some stimulus control and it is likely that this stimulus control generalized to the new splint and was then maintained while the splint was modified. It was clear, therefore, that stimulus control was not always associated with restriction of movement per se, but with another parameter of the splint, possibly pressure on the arm. The differential effect of the splint on different forms of self-restraint, both between and
within participants, further suggests that the parameter of stimulus control may be idiosyncratic. This idiosyncratic control, in turn, suggests that the overall efficacy of restraint fading may depend on fading along the critical parameters for any individual.

The process of generalization of stimulus control of zero levels of SIB warrants comment. In this study there was no reason to suspect that any environmental correlates of the social determinants of SIB varied significantly as free responding became possible. Consequently, it was unlikely that the discriminative stimuli or establishing operations that might have occasioned SIB in the past were absent when the splint was introduced and with the increase in flexion. As no other contingencies were intentionally manipulated, this suggests that the social reinforcement processes that are usually assumed to maintain SIB were inoperative (see Oliver, 1995). (Although this argument rests on the assumption that they did not change as a consequence of the intervention.) Given this rationale, it is possible that a nonsocial reinforcement process is operative. It is unlikely that automatic reinforcement is maintaining the SIB as it has not been extinguished (responding has not occurred without reinforcement, it has only been suppressed) and a preference for restraint is theoretically incompatible with the automatic reinforcement hypothesis (but see Fisher and Iwata, 1996, for a discussion of an approach-avoidance hypothesis that might counter this argument).

Romanczyk (1992) has argued that for some individuals, the antecedent to SIB may be the extreme anxiety or panic that accompanies restraint removal. This anxiety may act as an establishing operation for SIB, which is then negatively reinforced by the presentation of restraints accompanied by the reduction in anxiety. While the evidence for this model is primarily tangential, it does have the capacity to explain many of the paradoxical restraint phenomena that associate to severe SIB. It may also help to explain the process of the generalization of stimulus control during restraint fading considered above. The process may be likened to that of systematic desensitization by graded exposure. In the case of restraint fading, a parameter (or parameters) of the restraint are associated with low or no anxiety. This parameter (for example, touch) may be transferred to another parameter (for example flexion), via second-order conditioning or be retained while fading proceeds. If this interpretation is correct it adds to the understanding of stimulus control in restraint fading and may suggest the parameters that
should be subjected to manipulation.

A second possible explanation is that the presence of the restraints was associated with low levels of aversive social contact or high levels of positively reinforcing social contact. Consequently, the establishing operations for SIB are not present, non-self-injurious behaviors are introduced and maintained in the repertoire and come under the stimulus control of the presence of the splints and functionally displace SIB. The specific social interactions that might confirm this hypothesis were not appraised in this study and should be examined in future research. It is not inconceivable that the splints might change the behavior of those interacting with the individual wearing them. Smith, Iwata, Vollmer, and Pace (1992) and Derby, Fisher and Piazza (1996) have demonstrated that self-restraint may be maintained by negatively and positively reinforcing social contingencies.

These results are encouraging for the treatment of severe SIB when restraints are in use and responding is of dangerous frequency and intensity. Further research is necessary to establish the conditions under which the efficacy of restraint fading can be maximized. Such research might attend to whether a preference for restraint is evident, whether a single splint design can accommodate the majority of fading requirements, given idiosyncrasies in stimulus control, if intervention failure can be attributed to the loss of stimulus control when SIB and the device are paired and the data collection that should inform the pace and nature of fading.
REFERENCES


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FIGURE 1. Observed levels of self-punching, self-restraint, vocalizations, engagement, and social contact shown by Dawn during the experimental phase, comprising withdrawal designs to enable comparison of the new splints (s) with the previous restraints (pr), and the generalization phase, comprising probe observations and 17-month follow-up. The degree of flexion permitted by the splint is shown and a restriction index that evaluates the overall degree of restriction experienced by Dawn is also shown (see text).
FIGURE 2. Staff observations of self-punching, self-restraint, and vocalizations shown by Dawn when the previous restraints were in use and when the splint and flexion were introduced.
FIGURE 3. Observed levels of self-injurious behavior, self-restraint, vocalizations, engagement, and social contact shown by Dean when the previous form of restraint was in use and when the splint and flexion were introduced.
FIGURE 4. Observed levels of self-injurious behavior, self-restraint, vocalizations, engagement, and social contact shown by Sarah when the previous form of restraint was in use and when the splint and flexion were introduced.