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HEADBANGING BY PIGEONS: A SYSTEMATIC REPLICATION AND EXTENSION OF AN ANIMAL MODEL OF PSYCHOPATHOLOGY

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HEADBANGING BY PIGEONS: A SYSTEMATIC REPLICATION AND EXTENSION OF AN ANIMAL MODEL OF PSYCHOPATHOLOGY

By

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ABSTRACT

HEADBANGING BY PIGEONS: A SYSTEMATIC REPLICATION AND EXTENSION OF AN ANIMAL MODEL OF PSYCHOPATHOLOGY

By

Allison H. Hahn

Headbanging is a self-injurious behavior commonly associated with many forms of developmental and personality disorders, and major mental illnesses. Numerous successful interventions have been devised on the basis of considering self-injurious behavior as producing important reinforcing consequences for the individuals engaging in it. Accordingly, Layng, Andronis, & Goldiamond (1999) demonstrated that such behavior in pigeons could be established, maintained, and modified as operant behavior. In the present study, five White Carneaux pigeons were trained to bang their heads against a chamber wall equipped with a sensor grid that registered instances of the behavior and brought them into contact with experimentally arranged contingencies of reinforcement. Experiment 1 systematically replicated the initial findings of Layng et al. (1999); headbanging was maintained under a ratio schedule of food reinforcement like other more mundane ("normal") patterns of behavior (e.g., key-pecking). Experiments 2 and 3 demonstrated that headbanging could further be maintained by conditioned reinforcement (white keylights turned on) alone, which occasioned a VT schedule of food reinforcement, thus strengthening the heuristic value of this animal model for the study of self-injurious behavior.
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This thesis follows the format prescribed by the APA Style Manual and the Department of Psychology.
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Self-injurious behavior (SIB) is a behavior that results in physical damage to one’s own body without suicidal intent (Klonsky, 2007; Tate and Baroff, 1966). Self-injury is a severe behavior that is frequently reported in individuals with developmental disorders (e.g., autism and mental retardation) and psychiatric disorders (e.g., schizophrenia and borderline personality disorder). SIB is also common among individuals with some genetic disorders that are associated with developmental deficiencies (e.g., Lesch-Nyhan syndrome and Cornelia de Lange syndrome) (Schroeder et al., 2001).

Examples of common self-injurious behaviors include headbanging, biting, scratching, face slapping, and self-punching. In patients with Cornelia de Lange syndrome, the most common form of self-injury is skin picking, although other forms may also occur (e.g., headbanging) (Moss et al., 2005). All patients with Lesch-Nyhan syndrome exhibit SIB, usually involving biting of the lips or fingers, but other forms include headbanging or hitting other body parts (Anderson & Ernst, 1994).

Individuals without developmental disabilities may also self-injure. Self-injury in this population appears to be qualitatively different than the often repetitive self-injury by people with developmental disabilities (Schroeder et al., 2001). The most common type of self-injury in these individuals is skin-cutting (Klonsky, 2007).
Prevalence of Self-Injurious Behavior

SIB has been estimated to occur in approximately 4% of the general population and 21% of clinical patients who are not diagnosed with developmental disabilities or mental retardation (Briere & Gil, 1998). Estimates for the prevalence of SIB in patients diagnosed with developmental disabilities or mental retardation range from 3.5% to 46.6% (Bodfish, Crawford, & Powell, 1995; Kahng, Iwata, & Lewin, 2002; Winchel & Stanley, 1991). Within the published literature, headbanging is the most reported self-injurious behavior, followed by biting, in patients with developmental disabilities (Kahng et al., 2002). This was also reflected in a study by Rojahn, Matson, Lott, Esbensen, & Smalls (2001), which showed headbanging and biting to be the most prevalent forms of self-injury in a sample of patients with mental retardation.

Treatment

Self-injury may occur at high frequencies, and along with dangers posed to the individual emitting them, can be alarming to the individual’s family or caretaker. In order to reduce or eliminate SIB, effective treatment and the motivation behind the behavior need to be understood. Treatment of self-injury typically involves pharmacological or behavioral approaches, or some combination of the two.
Among individuals with developmental disabilities, SIB is correlated with neurochemical abnormalities involving dopaminergic, serotonergic, and/or endogenous opioid mechanisms (Schroeder et al., 2001).

Several uncontrolled open trials have shown a decrease in severity and frequency of self-injury with the use of serotonin reuptake inhibitors (SSRIs) (Matson et al., 2000). In patients with Lesch-Nyhan syndrome, self-injury has been hypothesized to be the result of low levels of serotonin. Low levels of serotonin have been linked to aggressive behaviors in animals (e.g., DiChiara, Camba, & Spano, 1971); patients with Lesch-Nyhan syndrome may self-injure as a form of aggression (Cataldo & Harris, 1982). Increased aggression has been observed in rats given p-chlorophenylalanine (PCPA), which inhibits serotonin production. When serotonin levels were increased in aggressive rats, by treatment with L-5-hydroxytryptophan (5-HTP) (a precursor to serotonin), or pargyline (a monoamine oxidase inhibitor), a decrease in aggression was observed (DiChiara et al., 1971).

In patients with Lesch-Nyhan syndrome a decrease in SIB was observed after serotonin levels were increased through administration of 5-hydroxytryptophan (5-HTP) and carbidopa; however, the patients became tolerant to its effects within a few months (Nyhan, Johnson, Kaufman, & Jones, 1980). Risperidone, a serotonin-dopamine antagonist, has also been found to be effective in reducing SIB in a patient with Lesch-Nyhan syndrome (Allen & Rice, 1996).

Serotonin may be a factor in many symptoms of autism. Potent serotonin transporter inhibitors, including tricyclic antidepressants (clominpramine) and selective...
serotonin reuptake inhibitors (fluoxetine, sertraline, fluvoxamine, and paroxetine), can reduce rituals and aggression in autistic patients. Repetitive behaviors and self-injury have been shown to worsen in autistic patients after tryptophan depletion, which decreases the production, release, and neurotransmission of serotonin (Cook & Leventhal, 1996). The serotonin uptake inhibitor, clomipramine, has been shown to be effective in the treatment of repetitive movement disorders, including self-injury, in patients with severe mental retardation (Lewis, Bodfish, Powell, & Golden, 1995).

A dopaminergic mechanism has also been linked to SIB in patients with Lesch-Nyhan syndrome. There is evidence that patients with Lesch-Nyhan syndrome have a dopamine deficiency. Postmortem examinations of patients with Lesch-Nyhan syndrome have shown lower dopamine concentrations in the striatum (Lloyd et al., 1981), and positron emission tomography (PET) imaging results have shown lower dopamine transporter sites in the caudate and putamen (Wong et al., 1996).

Traditionally, typical antipsychotics (e.g., thioridazine, haloperidol) have been used to treat patients with developmental disabilities. Studies have shown these drugs to be effective in reducing stereotyped behavior, but less effective in reducing SIB. In contrast, atypical antipsychotics (e.g., risperidone, olanzapine) appear to be more effective in reducing self-injury. Ten developmentally disabled patients with abnormal repetitive behaviors, who were previously treated with typical antipsychotics, showed a reduction in stereotypy and SIB when treated with the atypical antipsychotic, olanzapine (Turner & Lewis, 2002). A reduction in stereotypic SIB in patients with severe learning disabilities treated with olanzapine has also been reported (McDonough, Hillery, & Kennedy, 2000).
Atypical antipsychotics block both D_2 dopamine receptors and 5-HT_2 receptors (Turner & Lewis, 2002), but it has also been suggested that olanzapine has a high affinity for D_1 dopamine receptors, and a possible mechanism for stereotypic SIB may be supersensititity of the dopamine receptor D_1 in the corpus striatum (McDonough et al., 2000).

In order to better understand the role of dopamine in self-injury, animal models have been used. Pemoline-induced SIB was the first rodent model used to examine the neural mechanism of self-injury (King, 2002). Pemoline is an indirect monoamine agonist that blocks the uptake of dopamine and norepinephrine; however, the mechanism by which it produces SIB is unknown (Muehlmann, Brown, & Devine, 2008). Rats treated with pemoline will engage in self-biting behavior, primarily of the medial foreleg (King, 2002). This pemoline-induced self-biting behavior in rats is topographically similar to the obsessive SIB associated with Lesch-Nyhan syndrome (King et al., 1998). This has been shown to be a useful animal model of SIB that can be used to test the effectiveness of a variety of drug classes (Muehlmann et al., 2008), and has provided evidence for dopaminergic and glutamatergic interactions in the neostriatum during SIB (King et al., 1998).

Abnormalities in the opioid system have also been linked to SIB. There are two main opioid hypotheses of SIB: (1) self-injurious behavior is positively reinforced by the euphoric effects that result from the release of endogenous opiates (Winchel & Stanley, 1991; Schroeder et al., 2001) and (2) patients who self-injure have increased pain tolerance either by elevated endogenous opiates or supersensitive opiate receptors.
(Sandman, 2009). Both hypotheses implicate dysregulation of the opioid system, and opioid blockers would be logical treatments.

Studies have shown reduced SIB in patients treated with naltrexone, an opiate antagonist (Sandman, 2009). A comprehensive review of the scientific literature on the use of naltrexone for the treatment of SIB evaluated the drug’s efficacy in 86 patients. During naltrexone administration, 80% of subjects showed a decrease in SIB. In 47% of these subjects, their SIB was reduced by 50% or greater (Symons, Thompson, & Rodriguez, 2004). Long-term treatment of SIB with naltrexone may be effective without harmful side effects. In patients with dysregulation of the opioid system, naltrexone can be an effective treatment for severe SIB even when other treatments were unsuccessful (Sandman, 2009).

The exact neurochemical basis of SIB is unknown; dopaminergic, serotonergic, and endogenous opioid systems have been implicated as possible mechanisms. Successful drug treatments have been reported for each of these neurochemical systems, but there is no single pharmacological treatment that is effective in all patients. Along with pharmacological treatment, many patients can benefit from behavioral treatment.

ii. Behavioral Approaches

Self-injurious behavior has been explained within an operant behavior context. The strength and persistence of the behavior is determined by its consequences and the environment in which it occurs. The behavior is likely to occur in the presence of people and situations where the behavior has been reinforced in the past. It is less likely to occur in situations where the behavior has not been rewarded or has been punished (Favell et
Examining SIB in terms of operant behavior leads to determining the reinforcers maintaining the behavior. Once the reinforcers are understood, more effective treatments can be used.

Self-injury is primarily considered as a way to gain positive reinforcement (e.g., attention) or as an escape or avoidance of undesirable situations. However, the reinforcement that is maintaining the behavior can vary from one individual to another (Favell et al., 1982). Self-injury can be attention seeking (Lovaas, Freitag, Gold, & Kassorla, 1965; Lovaas & Simmons 1969; Moore, Mueller, Dubard, Roberts, & Sterling-Turner, 2002), avoidance or escape motivated (Carr, Newsom, & Binkoff, 1976; Edelson, Taubman, & Lovaas, 1983; Hagopian, Wilson, & Wilder, 2001), arousal increasing (Baumeister & Rollings, 1976; Edelson, 1984) or arousal decreasing (Cataldo, 1982), maintained by tangible reinforcers (Durand & Crimmins, 1988; Reed, Pace, & Luiselli, 2009), or maintained by sensory stimulation (Edelson, 1984). Not only can the reinforcement maintaining the SIB be different across individuals, self-injury can be maintained by multiple reinforcement contingencies within the same individual (Smith, Iwata, Vollmer, & Zarcone, 1993), or the contingency maintaining the behavior can change with time (Lerman, Iwata, Smith, Zarcone, & Vollmer, 1994).

One method of treatment for SIB uses differential reinforcement. This is a useful technique in the treatment of SIB maintained by positive reinforcement. In differential reinforcement of other behavior (DRO), a reinforcer is presented following periods during which no self-injury has occurred (Favell et al., 1982). Other forms of differential reinforcement include: differential reinforcement of alternative behavior (DRA) and differential reinforcement of incompatible behavior (DRI) (Borrero, Vollmer, Samaha,
Sloman, & Francisco, 2007). DRO can be successful in treating SIB; the rate of suppression of the behavior can be rapid, but the SIB may not be completely eliminated, and undesired or emotional side effects are possible (Cowdery, Iwata, & Pace, 1990). An evaluation of DRO procedures used to treat individuals whose SIB was positively reinforced by attention suggested that withholding the relevant reinforcer (i.e., attention) was essential for SIB to decrease, regardless of additional reinforcement during the absence of the aberrant behavior (Mazaleski, Iwata, Vollmer, Zarcone, & Smith, 1993).

Noncontingent reinforcement (NCR) is another method for treating SIB. With NCR, reinforcers are presented independent of any particular behavior, and instead are governed solely by a time-based schedule (Borreo et al. 2007). An advantage of NCR compared to DRO is that although the contingent relationship between the behavior and reinforcer is eliminated, reinforcement will still be frequently available independent of the individual’s behavior, whereas, with DRO, anytime the undesired behavior occurs, there will be a resulting loss of reinforcement. In addition to its advantages, NCR has been demonstrated to be as effective as DRO in reducing SIB that was attention seeking in patients with mental retardation (Vollmer, Iwata, Zarcone, Smith, & Mazaleski, 1993). In instances when the reinforcer maintaining the behavior cannot be identified or cannot be withheld, arbitrary reinforcers (i.e., those not related to maintaining the behavior) may be substituted as the reinforcer used during NCR. SIB has been shown to be suppressed when arbitrary reinforcers are delivered noncontingently, even if the maintaining reinforcer (e.g., attention) is still available when SIB occurs (Fischer, Iwata, & Mazaleski, 1997).
Another treatment approach involves extinction procedures. When extinction is used, the reinforcer for SIB is made no longer available. For example, caretakers must ignore self-injury by patients whose SIB is reinforced by attention. If self-injury is escape motivated, extinction requires that the possibility for escape be prevented (Favell et al., 1982). In seven developmentally disabled individuals whose SIB was avoidance- or escape-motivated, extinction procedures were reported to be effective in reducing or eliminating the SIB (Iwata, Pace, Cowdery, & Cataldo, 1990). DRO schedules used in conjunction with extinction were effective in suppressing SIB, but the same study reported low rates of SIB when extinction was used alone, suggesting that the extinction procedure was a crucial factor (Mazaleski et al., 1993).

Punishment is another behavioral approach that has been used to treat self-injury. Punishment procedures have used a variety of aversive stimuli that have been effective in treating SIB including: electric shock (Corte, Wolf, & Locke, 1971; Lovaas & Simmons, 1969; Tate & Baroff, 1966), aromatic ammonia (Tanner & Zeiler, 1975), citric acid squirted in the mouth (Mayhew & Harris, 1979), and water mist sprayed on the face (Dorsey, Iwata, Ong, & McSween, 1980).

In the 1970s and 1980s reinforcement-based treatments were as likely to be used as punishment. Since the 1990s, there has been an increase in the number of treatments that focus on reinforcement alone, and an accompanying decrease in the number that use punishment. Along with the increase in reinforcement-based techniques there has also been an increase in the use of functional assessment procedures (Kahng et al., 2002).

Traditionally, reinforcers were chosen based on what was assumed to be reinforcing or what was successful in the treatment of other patients, and not based on
what was reinforcing for that specific individual. Current standards in treatment rely on evaluating reinforcers that maintain SIB, and selectively changing the behavior (DeLeon, Rodriguez-Catter, & Cataldo, 2002). Behavioral treatments can be effective for a variety of patients, including patients whose self-injury is primarily considered biological. For example, SIB in patients with Lesch-Nyhan syndrome can be suppressed with a variety of behavioral treatments, including DRI, DRO, and extinction procedures (Olson & Houlihan, 2000).

Functional assessment procedures can be used to develop successful behavioral treatments. Functional assessment procedures identify the antecedent conditions in which the problem behavior occurs and the reinforcers that are maintaining the behavior. Iwata, Roscoe, Zarcone, and Richman (2002) described three general categories of functional assessment procedures (1) experimental (functional) analyses, (2) descriptive analyses, and (3) indirect assessments.

With the experimental analysis approach, variables that are thought to be maintaining the behavior are systematically manipulated and the effects on the behavior are observed. Iwata et al. (1994) conducted a functional assessment on the reinforcers maintaining SIB in 152 individuals with developmental disabilities. The reinforcers and their corresponding prevalence rates that were reported include: social-negative reinforcement (i.e., escape from aversive stimuli), 38.1%; social-positive reinforcement (i.e., attention or tangibles), 26.3%; automatic reinforcement (i.e., sensory), 25.7%; multiple controlling variables, 5.3%; and undetermined variables, 4.6%.

The descriptive analysis approach also involves repeated observations of the behavior, but no direct manipulation of the variables is performed. Behaviors are
observed in an effort to identify behavioral patterns, but the results are correlational.
Lerman and Iwata (1993) compared the conclusions of descriptive and experimental
analyses and concluded that the descriptive analysis was as effective as the experimental
analysis at identifying the variables maintaining self-injurious behavior that is being
socially reinforced (e.g., a caregiver is present or not), but the descriptive analysis was
not able to differentiate if the social reinforcement was positive or negative (i.e., attention
or escape).

The indirect approach of functional assessment uses questionnaires or rating
scales to assess the variables maintaining SIB. One example of an indirect approach is
the Motivation Assessment Scale (MAS), which is a questionnaire developed to
determine the influence of a variety of variables on self-injury. Indirect assessments are
simple and require less time than other functional assessment approaches; however,
examinations of the reliability of the MAS have had mixed results (e.g., Durand &

Self-injurious behavior can be treated using behavioral methods based on operant
conditioning. The antecedent conditions under which the behavior occurs and the
reinforcers that maintain the behavior can vary from individual to individual. In order to
provide an individual with the best behaviorally-based treatment, functional assessment
procedures can be used to determine the reinforcers maintaining the behavior. There are
numerous behaviorally-based treatments that have been demonstrated to be effective in
suppressing or eliminating SIB, and these behavioral methods were first evaluated using
nonhuman animals in the laboratory.
Animal Models

Humans engage in a variety of behaviors within their day-to-day lives, many of which appear to be determined in complex ways; nevertheless, most can be explained in simpler terms, and the variables maintaining these behaviors can be explored and better understood by using nonhuman animals to model the behavior. The effects of schedules of reinforcement, aversive stimuli, and discriminative stimuli on behavior can be examined within the experimental laboratory using animals as subjects (Ferster, 1966).

Accordingly, animals can be used as models for abnormal behavior or other behavioral problems, allowing researchers to investigate treatments for these behaviors that can then be applied to the human population. The link between nonhuman animal research and the treatment of human patients is most obvious when you consider functional assessment procedures; both functional assessment procedures (specifically experimental analyses) and research using animal models directly manipulate the reinforcer(s) maintaining the behavior (Borrero et al., 2007). Borrero et al. (2007) described the relationship between animal models and human application as bidirectional; reinforcers can be identified and controlled using animal models and this can be applied to human treatments, or reinforcers identified during functional assessment procedures can be used to guide what research is conducted within the animal laboratory.

There are several benefits to doing research with animal models. The researcher can better control for extraneous variables and maintain the subjects in a more controlled environment than is possible with human subjects. As the effectiveness of treatment procedures are initially tested, there are additional concerns when using human subjects who may injure themselves or others. Animal models can be used in these initial
treatment evaluations, especially where alternating baseline and experimental conditions need to be compared (a tactic requiring an experimenter to withdraw a demonstrably effective treatment and observe whether the problem behavior returns) (Borrero et al., 2007).

Self-injurious behavior has been observed in captive animals. Rhesus macaque monkeys (*Macaca mulatta*) who were raised in partial and total isolation may exhibit abnormal behaviors that are collectively called “isolation syndrome” (Novak, Crockett, & Sackett, 2002). Self-directed and stereotyped behaviors are two examples of the abnormal behaviors observed. (Novak et al., 2002). When compared to isolation reared pigtail (*M. nemestrina*) and crab-eating macaques (*M. fascicularis*), isolation reared rhesus macaques developed the most isolation syndrome behaviors, suggesting that the effects of isolation rearing can vary with species (Sackett, Ruppenthal, Fahrenbruch, Holm, & Greenough, 1981).

Self-biting was a severe behavior that developed in isolation reared monkeys. Males were more likely to self-bite than females (Mitchell, 1979). Few cases of self-biting led to actual self-injury; in most instances, this behavior should be considered potentially self-injurious behavior. However, in some cases of actual self-injury, the animal required medical attention, and a few monkeys would repeatedly self-injure. Conversely, monkeys who were reared and housed socially rarely developed SIB (Novak et al., 2002). Other forms of SIB have also developed in primates; a rhesus macaque raised in isolation exhibited headbanging in situations related to certain environmental events (e.g., transferring to a new cage) (Levison, 1970).
Isolation reared primates can serve as an animal model for human SIB; however, primate research examining the abnormal behaviors produced by total social isolation rearing had stopped by the mid-1980s. Monkeys who are socially reared, but housed individually as adults for long periods, may also exhibit abnormal behavior, including SIB, and these primates can also be a useful animal model of SIB (Novak et al., 2002). In one primate facility, 14% of individually housed rhesus macaques were documented as having SIB. The majority of these monkeys were male (96%). Monkeys who were removed from social groups and housed individually at a younger age and those who were exposed to stressors (e.g., medical/veterinary procedures) were more likely to develop SIB (Novak, 2003).

Operant conditioning can be used to modify abnormal behavior, including self-injury in captive animals. Numerous behavioral treatments for SIB have been demonstrated to be effective in human patients, and most of these can be applied to similar abnormal behaviors in captive primates (Bloomsmith, Marr, & Maple, 2007).

SIB in a chimpanzee (Pan troglodytes troglodytes) was successfully reduced using a combination of treatments: pharmacological and behavioral (i.e., positive reinforcement), as well as environmental and social enrichment. The severity of SIB in this chimpanzee required immediate therapy, so a functional assessment was not conducted and each treatment was not evaluated independently (Bourgeois, Vazquez, & Brasky, 2007). However, functional assessment procedures can be used to determine the maintaining reinforcers and develop treatments for abnormal behaviors in nonhuman primates. Through a functional assessment procedure, it was determined that human attention was maintaining the SIB of a captive olive baboon (Papio hamadryas anubis).
Differential reinforcement of an alternative behavior (i.e., lip smacking) was used as treatment, which resulted in decreased SIB (Dorey, Rosales-Ruiz, Smith, & Lovelace, 2009).

SIB has also been established and extinguished as an operant behavior in rhesus monkeys. Paw-to-head hitting was established and brought under stimulus control; however, attempts to shape head-to-wall banging were unsuccessful (Schaefer, 1970).

While the previous examples of animal models of SIB have used primates, other species can also serve as models of SIB. Layng, Andronis, and Goldiamond (1999) demonstrated that headbanging by pigeons could be established, maintained, and modified as an operant behavior. Headbanging by pigeons is not a naturally occurring behavior. However, it can be brought under the control of contingencies similar to key-pecking, treadle-pressing, or similar behaviors, which are considered “normal.” The objective of the current study is to replicate and extend the previous findings.

Experiment 1 is a systematic replication of establishing and maintaining headbanging as a behavior by reinforcing it directly with food. Experiment 2 establishes headbanging as a behavior that is never directly reinforced with food, but changes a discriminative stimulus associated with a schedule of food reinforcement that is response-independent. The pigeons used in Experiment 2 have no history of being directly reinforced with food for headbanging. Experiment 3 uses the same procedure as Experiment 2, in which headbangs change a discriminative stimulus that is associated with a response-independent schedule of food reinforcement. However, the pigeons used in Experiment 3 have a history of being directly reinforced with food for banging their heads.
METHODS

Subjects

Five male White Carneaux pigeons (*Columba livia*), approximately five years old, served as subjects. The birds had served as subjects in a previous experiment unrelated to the current research, but were experimentally naïve with regard to headbanging. The birds were divided into two groups; Group One consisted of two pigeons, designated PP31 and PP38, and Group Two consisted of three pigeons designated PP35, PP36, and PP37. All birds were maintained at approximately 80% (± 5%) their individual weights when fed *ad libitum*. Birds had free access to grit and fresh water in their home cages, but were fed almost exclusively through the procedures implemented during experimental sessions. Additional food was provided to a bird following the experimental session, if its weight fell below criterion.

Apparatus

Two identical Lehigh Valley operant chambers were used (Model 1519C). The size of the enclosed space in each chamber was 10.5” x 12” x 13”. Both were equipped with Lehigh Valley grain dispensers (Model 1347) and three Lehigh Valley pecking keys (Model 1348), completely covered with a translucent plastic shield to diffuse the light from the keys. The feeder opening in each chamber was 1.875” x 2.375”. The front wall of each chamber was replaced with a flexible Plexiglas panel with a 14.5 cm x 8 cm wire grid woven into it (see Figure 1), to register contacts by the top of a bird’s head with the
wall. Lights and feeders in both chambers are controlled simultaneously by the same microcomputer.

Each chamber contained a ventilation fan, and a 28 volt bayonet white light bulb (houselight); the houselight was on in each chamber during the session, but turned off whenever grain was made available in the food dispenser. A white noise generator was turned on in the room to mask background noises throughout the sessions. Sessions were monitored in a room adjacent to the experimental room via closed-circuit television. Some sessions were also recorded with a video camera.

Data were recorded, and experimental events were controlled by a desktop computer in the experimental room. The respective programs that controlled each phase of the experiments, written in Med-PC for Windows™, are included in Appendix A.

**Fig. 1.** Experimental chamber. Shows the internal view of the experimental space with white keylights above feeder opening (*left*) and front wall with wire grid (*right*).

**General Procedure**

Each pigeon was fitted with a small Velcro® pad placed approximately 0.5 cm above the base of its beak (see Figure 2). One side of the Velcro® pad was glued directly to each bird’s head with Elmer’s™ Glue. The other side of the pad had a piece of aluminum foil attached to the sticky adhesive. If the aluminum foil became worn, the
aluminum-sided pad could be replaced and the other pad would remain attached to the bird.

When the aluminum pad came into contact with the interwoven wire grid on the front of the chamber, a connection was made and recorded on the computer. All headbangs and food deliveries were controlled and recorded by the computer. Cumulative records of headbangs and food deliveries were created using Med-PC SoftCR™. Sessions were run seven days per week and each daily session lasted 30 to 60 minutes (depending upon the particular phase of the experiments).

![Protective headgear affixed to pigeon’s head.](image)

Figure 2. Protective headgear affixed to pigeon’s head.

**Specific Procedures**

*i. Experiment 1*

The procedure in Experiment 1 was a systematic replication of the experiment conducted by Layng et al. (1999). Two pigeons, PP31 and PP38, served.

The birds were trained to make head-contact with the wire grid using standard operant shaping procedures. Initially, each headbang was reinforced with a food delivery (continuous reinforcement). The number of headbangs required for reinforcement was gradually increased until 40 headbangs were required for each food delivery (a fixed ratio 40 [FR-40] schedule). The total session duration was set at 30 minutes.
ii. Experiment 2

Group Two subjects, PP35, PP36, and PP37 were initially placed on a variable-time (VT) schedule of reinforcement. In this phase, the white keylights were turned on, and food deliveries were programmed to occur at varying times, independent of the subjects’ behavior. The total session duration was set at 40 minutes.

Subsequently, these birds were subjected to a Multiple VT:EXT schedule with 10 minute phase changes between VT-30 sec and extinction schedules, accompanied by white keylights and only the white houselight, respectively. Because these pigeons had been trained in a previous experiment to peck the lighted keys, initially key-pecking was observed. The chamber was then modified by placing a translucent Plexiglas strip over the keylights, and key-pecking subsequently stopped.

Pigeons in Group Two were then trained, by successive approximations, to bang their heads, in a two-phase procedure. These sessions lasted 60 minutes apiece. During the first phase, under a white houselight, each headbang would cause a transition to the second phase for 15 seconds. During the second phase, the white keylights were turned on, and a VT-10 sec schedule of food reinforcement was in effect. No further responses were needed for food to be delivered during these 15 second periods. However, each additional headbang during the second phase reset the Phase 2 timer for an additional 15 seconds. In other words, with additional headbangs under Phase 2, the keylights could remain on throughout an experimental session. Under these conditions, headbanging was reinforced by a conditioned reinforcer, the white keylights. The white keylights had become a conditioned reinforcer, because food was delivered in the presence of the white
keylights. A three second changeover delay (3-sec COD) was implemented such that no programmed food delivery could occur for at least three seconds after any headbang during Phase 2.

Initially, Phase 1 headbanging was maintained on a continuous reinforcement schedule (CRF). In other words, each headbang resulted in the white keylights being turned on. In the next procedure, headbanging under Phase 1 was maintained on a fixed ratio schedule with the conditioned reinforcer (white keylights) made contingent upon a fixed number of headbangs. The required number of headbangs was increased until five headbangs were required to turn on the white keylights (fixed ratio 5 [FR-5]). Once the white keylights were turned on, a VT-10 sec schedule of food reinforcement began. While the white keylights were on, only one additional headbang was required to reset the Phase 2 timer for an additional 15 seconds; as before, by banging its head at least once before the Phase 2 timer expired, a bird could maintain the white keylights and VT schedule continuously throughout a session once Phase 2 was entered.

iii. Experiment 3

Pigeons in Group One (PP31 and PP38) were also subjected to the two-phase procedure described in Experiment 2. During the first phase, under a white houselight, each headbang would cause a transition to the second phase for 15 seconds. During the second phase, the white keylights were turned on, and a VT-10 sec schedule of food reinforcement was in effect. No further responses were needed for food to be delivered during these 15 second periods. However, each additional headbang during the second phase reset the Phase 2 timer for an additional 15 seconds. Initially, Phase 1 headbanging
was maintained on a continuous reinforcement schedule (CRF), but in another procedure, Phase 1 headbanging was maintained on a fixed ratio schedule with the conditioned reinforcer (white keylights) made contingent upon a fixed number of headbangs. Five headbangs were required to turn on the white keylights during Phase 1 (fixed ratio 5 [FR-5]), which led to a VT-10 sec schedule of food reinforcement (Phase 2). While the white keylights were on, only one additional headbang was required to reset the Phase 2 timer for an additional 15 seconds. Group 1 pigeons used in Experiment 3 had no previous experience with the white keylights; previously, their headbangs had been reinforced directly with contingent food deliveries.
RESULTS

Experiment 1

During Experiment 1, the pattern of headbanging by pigeons PP31 and PP38 was characteristic of typical operant behavior. The rate of responding increased as the number of responses required for reinforcement increased according to the schedule of reinforcement. The schedules of reinforcement that were used during Experiment 1 and the number of sessions per schedule for each pigeon are listed in Table 1.

Figure 3 depicts headbangs and reinforcers per minute for PP31 and PP38, respectively, during fixed ratio schedules. For PP31, during CRF, the number of headbangs per minute ranged between 3 and 8. For the same bird, during FR40, the number of headbangs per minute was substantially above the rate exhibited during CRF; up to approximately 70 headbangs per minute was recorded. Similar results were found for PP38; during CRF the number of headbangs ranged between less than one per minute and 10 per minute. For the same bird, during FR40, the number of headbangs per minute increased, and up to approximately 40 headbangs per minute was recorded during a session.

Throughout Experiment 1, the rate of reinforcers per minute paralleled the rate of headbanging per minute for both PP31 and PP38 (Fig. 3), as would be expected for a fixed ratio schedule of food reinforcement. As Figure 3 shows, unsurprisingly, the number of reinforcers per minute and the number of headbangs per minute are equal during CRF. As the number of headbangs required for reinforcement was increased
according to each schedule of reinforcement, the separation between the two lines on the chart representing reinforcers per minute and headbangs per minute increased proportionately.

For PP31, the number of headbangs per minute varied during FR5, but became more steady as the schedule requirements were increased. A steady decrease in responding occurred during FR35 (starting at approximately day 136), but during FR40, the behavior reached a relatively steady state (at approximately day 161) and continued through the duration of Experiment 1 (Fig. 3). PP38 exhibited the same variability in headbanging throughout FR3. During FR30 through FR40, his rates varied moderately, but the overall pattern showed a slight increase in the behavior, although there were a few sporadic days where the behavior decreased greatly (e.g., days 171; 176) (Fig. 3).

During Experiment 1, the pigeons exhibited a characteristic pattern of responding under an FR40 schedule of food reinforcement (Fig. 4). They responded rapidly, taking a short pause immediately after reinforcement (designate as a hatch-mark (\) on the cumulative record), and then continued to respond at a high rate. This is called a break and run pattern and is a typical pattern under FR schedules, regardless of the behavior that is being reinforced.

There was variability in the overall response rate from session-to-session. This is evident by looking at the rate of headbanging per minute across sessions (Fig. 3). However, it is important to note that while the overall response rate may decrease during a session, the local response rate remained relatively stable across sessions. This can be seen by looking at the cumulative records. For example, Figure 5 shows a cumulative record for PP38 under an FR40 schedule of food reinforcement. The local rate of
responding (e.g., between minute 3 and 6) is comparable to the rate of responding for PP38 in Figure 4. However, in Figure 5, there are longer pauses after reinforcement (e.g., between minute 12 and 17). In sessions where these long pauses are taken, the overall response rate will be lower (i.e., fewer headbangs per minute), although the local response rate remains relatively high across sessions.

Figure 6 represents a scatterplot of headbanging per minute during Experiment 1 as a function of body weight (gms) for PP31 and PP38, respectively. For PP31, no true linear trend was observed; body weight accounted for none of the total variance in the number of headbangs per minute. Similar results were found for PP38; body weight only accounted for 3.8% of the total variance in the number of headbangs per minute.

Figure 3 shows sharp decreases in headbanging per minute that occurred sporadically throughout the sessions. Much of this variability during Experiment 1 can be attributed to issues with the headgear on pigeons PP31 and PP38. The main problems that occurred with the headgear were: (1) the aluminum foil would wear away, and (2) pigeon “dust” would accumulate on the headgear. Both of these problems resulted in headbangs not being properly registered and recorded. As soon as these problems with the headgear were realized, steps to prevent them from reoccurring were implemented, including: (1) replacing the aluminum foil side of the helmet when it was beginning to wear away (approximately once a week), and (2) cleaning the aluminum foil with an alcohol wipe before every session. Once these problems were addressed, the sporadic decreases in the rate of responding were reduced, which can be verified by Figure 3. For example, on day 162, PP31’s headgear was replaced. In the four previous days, his response rates had rapidly decreased, but once the headgear was replaced, his rates
greatly increased and remained stable for the rest of Experiment 1. Similarly, on day 183, PP38’s headgear was replaced. During the two previous sessions, his rate of responding was low, but once the headgear was replaced, his rates increased and remained high for the remainder of Experiment 1.

Table 1. Number of experimental sessions for each procedure during Experiment 1 for pigeons PP31 and PP38.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Number of Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PP31</td>
</tr>
<tr>
<td>CRF</td>
<td>12</td>
</tr>
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<td>5</td>
</tr>
<tr>
<td>FR40</td>
<td>42</td>
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Figure 3. Standard celeration charts from Experiment 1. Results of Experiment 1 for pigeons PP31 (top) and PP38 (bottom). The data include headbangs per minute, represented by filled circles (■), and reinforcers per minute, represented by x’s (x). A dashed vertical line indicates a change in experimental conditions. The solid horizontal line indicates the record floor (the point at which one observed event per session would be depicted.)
Figure 4. Cumulative records from Experiment 1. Shows typical cumulative records of headbanging by pigeons PP31 (top) and PP38 (bottom) in Experiment 1 under an FR40 schedule of food reinforcement.
Figure 5. Cumulative record for PP38 from Experiment 1 under an FR40 schedule of food reinforcement.
Figure 6. Number of headbangs per minute during Experiment 1 as a function of body weight (gms) in pigeons PP31 (top) and PP38 (bottom).
Experiment 2

Before pigeons in Group Two (PP36, PP37, & PP38) were trained to headbang, they were subjected to a Multiple VT:EXT schedule. A typical cumulative record from each bird under this schedule is depicted in Figure 7. For the first 10 minutes, the birds were under a VT-30 sec schedule, while the white keylights were on. For the next 10 minutes, an extinction schedule was in place, while only the houselight was on. This was then followed by an additional 10 minute VT-30 sec schedule, and 10 minute extinction schedule, respectively. Food deliveries are shown by a hatch-mark (\) on the cumulative records. Food was only delivered during the VT schedules, not the extinction schedules.

During the Multiple VT:EXT schedule, subject PP37 showed discriminative control by the white keylights ($S^D$) over his behavior in the chamber (Fig. 8). During $S^D$, he would pace back-and-forth in front of the keylights on the side-wall, but during $S^A$, he would face the front wall or explore the rest of the chamber.

During Experiment 2, the pattern of headbanging by pigeons PP35, PP36, and PP37 was characteristic of typical operant behavior. The rate of responding during the Multiple VT:EXT schedule was low (if any), but increased related to the contingency that was imposed. The schedules of reinforcement that were used during Experiment 2 and the number of sessions per schedule for each pigeon are listed in Table 2.

Figure 9 shows the headbangs per minute during Phase 1 and Phase 2, and the food reinforcers per minute during Experiment 2 for PP35, PP36, and PP37. Unlike the pigeons used in Experiment 1, the birds used during Experiment 2 had no history of being reinforced directly with food for banging their heads. During the Multiple VT:EXT schedule (before training) two of the birds did head bang, but at very low rates. PP35 and
PP37 occasionally headbanged, but less than once per minute; PP36 did not headbang during the Multiple VT:EXT schedule (Fig. 9). The rates of responding increased for all three birds once the white keylights being turned on was made contingent on headbanging. The white keylights became a conditioned reinforcer for headbanging. Initially, under this procedure, PP35 headbanged a little over once a minute, but his rates increased to over 10 per minute. PP36 initially headbanged approximately once every 30 seconds, but his rates increased to 10 per minute. PP37 initially headbanged less than once every 30 seconds, but his rates increased to 5 per minute (Fig. 9).

Across sessions, PP36 and PP37 banged their heads the most during Phase 1 (compared to Phase 2 headbangs). When Phase 1 was a CRF schedule of reinforcement, PP35 did most of his headbanging during Phase 2 (the white keylights were already on). However, once the schedule of reinforcement during Phase 1 was changed to an FR5, his number of Phase 2 headbangs decreased rapidly, and most his headbangs occurred during Phase 1 (Fig. 9).

Figure 10 shows cumulative records from PP35, PP36, and PP37 during Experiment 2, when each headbang during Phase 1 resulted in the white keylights being turned on (CRF). All three birds responded at steady rates, although PP36 and PP37 responded at an overall lower rate than PP35. Figure 11 shows cumulative records for the same birds during another schedule of reinforcement, when five headbangs were required to turn on the white keylights (fixed ratio 5 [FR-5]). Under both of these schedules of reinforcement, once the white keylights were turned on, a VT-10 sec schedule of food reinforcement began. Under this schedule, the overall rate increased for all three birds. For PP37, the local rate of responding increased, but he also exhibited
longer pauses after some instances of reinforcement (e.g., between minute 24 and 27), which, as mentioned previously, leads to a lower overall response rate (Fig. 11).

Table 2. Number of experimental sessions for each procedure during Experiment 2 for pigeons PP35, PP36, and PP37.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Number of Sessions</th>
<th>Subject</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>PP35</td>
<td>PP36</td>
</tr>
<tr>
<td>Multiple VT:EXT</td>
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<td>30</td>
</tr>
<tr>
<td>HB (CRF)→VT</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>HB (CRF)→(4” fd del)</td>
<td>53</td>
<td>12</td>
</tr>
<tr>
<td>HB (FR2)→VT20”</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>HB (FR2)→VT10”</td>
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<td>36</td>
</tr>
<tr>
<td>HB (FR5)→VT</td>
<td>19</td>
<td>19</td>
</tr>
</tbody>
</table>
Figure 7. Typical cumulative records for pigeons PP35, PP36, and PP37 in Experiment 2 under a Multiple VT:EXT schedule.

Figure 8. Pigeon PP37 showing discriminative control by white keylights ($S^D$) over his behavior in the chamber.
Figure 9. Standard celeration charts from Experiment 2 for Group Two pigeons. Results of Experiment 2 for pigeons PP35 (top), PP36 (middle) and PP37 (bottom). The data include headbangs during Phase 1, represented by filled triangles (■), headbangs during Phase 2, represented by open triangles (△), total headbangs per minute, represented by filled circles (●), and reinforcers per minute, represented by x’s (x). A dashed vertical line indicates a change in experimental conditions. The solid horizontal line indicates the record floor (the point at which one observed event per session would be depicted.)
Figure 10. Cumulative records from Experiment 2 [HDBG (CRF) → VT]. Shows typical cumulative records of headbanging by pigeons PP35 (top), PP36 (middle), and PP37 (bottom) in Experiment 2 under a two-phase procedure. (Phase 1: each headbang turned on white keylights and caused a transition to the second phase for 15 sec. Phase 2: VT-10 sec schedule of food reinforcement).
Figure 11. Cumulative records from Experiment 2 [HDBG (FR5) → VT]. Shows typical cumulative records of headbanging by pigeons PP35 (top), PP36 (middle), and PP37 (bottom) in Experiment 2 under a two-phase procedure. (Phase 1: an FR5 schedule of headbanging turned on white keylights and caused a transition to the second phase for 15 sec. Phase 2: VT-10 sec schedule of food reinforcement).

**Experiment 3**

The schedules of reinforcement that were used during Experiment 3 and the number of sessions per schedule for each pigeon are listed in Table 3. The pigeons from Experiment 1 were used in Experiment 3 and had a previous history of being directly reinforced for headbanging with food.

Figure 12 shows the headbangs per minute during Phase 1 and Phase 2, and the food reinforcers per minute during Experiment 3 for PP31 and PP38. For both birds, the total number of headbangs was highest during the initial sessions. In subsequent sessions, this response rate began to steadily decline (for PP31 this decline can be seen through day 38; for PP38 this decline can be seen through day 23). Even with this decline, the number of food reinforcers per minute remained relatively stable for both birds, suggesting that the behavior decreased because high rates of responding were no
longer paying off with more food reinforcement (as in Experiment 1). For PP31, initially, most headbangs occurred during Phase 2 (the white keylights were already on). However, when Phase 1 was changed to an FR5 schedule of reinforcement, the number of Phase 2 headbangs decreased, and the number of Phase 1 headbangs increased. For PP38, initially, most headbangs occurred during Phase 2, but around session 23, the number of headbangs during Phase 2 decreased and remained low for most of the remaining sessions. (Higher instances of Phase 2 headbangs were recorded for some sessions: e.g., day 31; day 48.) When Phase 1 was changed to an FR5 schedule of reinforcement, the number of Phase 2 headbangs greatly decreased (some sessions had no occurrences of Phase 2 headbangs), and most headbangs occurred during Phase 1 (Fig. 12).

Figure 13 shows cumulative records from PP31 and PP38 during Experiment 3, when each headbang during Phase 1 resulted in the white keylights being turned on (CRF). Both pigeons exhibited steady responding, although the overall rate of responding is lower than the response rate during Experiment 1 (Fig. 4). Figure 14 shows cumulative records for the same birds during another schedule of reinforcement, when five headbangs were required to turn on the white keylights (fixed ratio 5 [FR-5]). Under both of these schedules of reinforcement, once the white keylights were turned on, a VT-10 sec schedule of food reinforcement began. Under this schedule, there was little change in the overall response rate, but it remained lower than the rate of responding during Experiment 1 (Fig. 4).

Figure 15 represents a scatterplot of headbanging per minute as a function of body weight (gms) for PP31 and PP38, respectively. For PP31, no true linear trend was
observed, and body weight only accounted for 9.4% of the total variance in the number of headbangs per minute. Similar results were found for PP38; body weight only accounted for 3.0% of the total variance in the number of headbangs per minute.

Table 3. Number of experimental sessions for each procedure during Experiment 3 for pigeons PP31 and PP38.

<table>
<thead>
<tr>
<th>Procedure</th>
<th>Number of Sessions</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Subject</td>
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<tr>
<td></td>
<td>PP31</td>
</tr>
<tr>
<td>HB (FR10) → VT (30min session)</td>
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</tr>
<tr>
<td>HB (CRF) → VT (60 min session)</td>
<td>3</td>
</tr>
<tr>
<td>HB (CRF) → VT (4” fd del)</td>
<td>53</td>
</tr>
<tr>
<td>HB (FR5) → VT</td>
<td>19</td>
</tr>
</tbody>
</table>
Figure 12. Standard celeration charts from Experiment 3 for Group One pigeons. Results of Experiment 3 for pigeons PP31 (top) and PP38 (bottom). The data include headbangs during Phase 1, represented by filled triangles (-▲-), headbangs during Phase 2, represented by open triangles (-△-), total headbangs per minute, represented by filled circles (-●-), and reinforcers per minute, represented by x’s (-x-). A dashed vertical line indicates a change in experimental conditions. The solid horizontal line indicates the record floor (the point at which one observed event per session would be depicted.)
Figure 13. Cumulative records from Experiment 3 [HDBG (CRF) → VT]. Shows typical cumulative records of headbanging by pigeons PP31 (top) and PP38 (bottom) in Experiment 3 under a two-phase procedure. (Phase 1: each headbang turned on white keylights and caused a transition to the second phase for 15 sec. Phase 2: VT-10 sec schedule of food reinforcement).
Figure 14. Cumulative records from Experiment 3 [HDBG (FR5) → VT]. Shows typical cumulative records of headbanging by pigeons PP31 (top) and PP38 (bottom) in Experiment 3 under a two-phase procedure. (Phase 1: an FR5 schedule of headbanging turned on white keylights and caused a transition to the second phase for 15 sec. Phase 2: VT-10 sec schedule of food reinforcement).
Figure 15. Number of headbangs per minute during Experiment 3 as a function of body weight (gms) in pigeons PP31 (top) and PP38 (bottom).
DISCUSSION

The present study shows that headbanging by pigeons, a behavior that is not naturally occurring in this species, can be established and maintained under various experimental contingencies. Headbanging was maintained with unconditioned positive reinforcement and conditioned positive reinforcement. Experiment 1 systematically replicated the findings of Layng et al. (1999).

In Experiment 1, headbanging was maintained under a ratio schedule of food reinforcement like other more mundane (“normal”) patterns of behavior. Successful treatments have been implemented on the basis of considering SIB as operant behavior, which produces important reinforcing consequences for the individuals engaging in it. SIB can be reinforced by attention (Lovaas et al., 1965; Lovaas & Simmons, 1969; Moore et al., 2002), tangibles (Durand & Crimmins, 1988; Reed et al., 2009), and avoidance or escape from undesirable situations (Carr et al., 1976; Edelson et al., 1983; Hagopian et al., 2001).

Understanding the reinforcers that are maintaining the problem behavior is important when trying to implement effective treatment. For example, if a patient’s self-injury is attention seeking, attending to the person while they engage in self-injury, will actually maintain the problem behavior. However, there may be situations where the behavior is not obviously being reinforced. In these instances, something in the environment may be acting as a discriminative stimulus, and the behavior is being maintained. This notion led to the rationale for Experiments 2 and 3. Can a
discriminative stimulus (i.e., white keylights) act as a conditioned reinforcer (a stimulus that is reinforcing headbanging) and maintain the behavior?

Experiments 2 and 3 demonstrated that headbanging could further be maintained only by conditioned reinforcement (white keylights turned on) that occasioned a VT schedule of food reinforcement. It should be noted that in Experiment 2, during the initial VT schedule of reinforcement, some headbanging was recorded for PP35 and PP37 (see Fig. 9), even though they had not yet been trained (by successive approximations) to do this behavior. These “headbangs” may have just been the result of the bird repeatedly moving its head close to the front wall and making contact with the sensor grid, or a food reinforcement may have coincidentally followed a headbang, reinforcing the behavior, and creating superstitious responding. However, as Figure 9 shows, the headbangs during the VT schedule occurred at a lower rate when compared to the rate of headbanging after the training took place, which would be expected.

The procedures used in Experiments 2 and 3 were identical, but the birds used in each experiment had a different history, with regard to headbanging. The pigeons used in Experiment 2 had no previous history of headbanging, while the pigeons used in Experiment 3 had a history of headbanging directly for food reinforcement. It is interesting to note, that regardless of the history with headbanging, within both groups there was variability in the rate of responding. In each group, there was one bird whose rate of responding averaged at least twice the rate of the other bird(s) in that group. For Group One, the mean and median for the number of headbangs per minute for each bird were: PP31, mean = 22.7, median = 14.0; PP38, mean = 3.0, median = 2.3. For Group Two, the mean and median for the number of headbangs per minute for each bird were:
Collectively, one group of birds did not respond at a higher rate when compared to the other group. This variability suggests that the rate of responding may differ between birds, regardless of their histories, and the ultimate contingency takes control regardless of the origin of the behavior.

During Experiments 2 and 3, headbangs were not being directly reinforced with food, but headbangs resulted in the conditioned reinforcer (i.e., white keylights). Additionally, the white keylights served as a discriminative stimulus, because once the keylights were on, grain deliveries would occur on a VT schedule. Although the pigeons in Experiments 2 and 3 were receiving food reinforcement, the three second changeover delay, prevented the occurrence of a grain delivery immediately following a headbang.

This reinforcement schedule is analogous to circumstances in applied settings where self-injury ensures the presence of staff who then control access to various other reinforcement contingencies. Using the previous example of a patient whose SIB is attention-seeking, the SIB may occur anytime the patient is around a caregiver, because the caregiver is a stimulus in whose presence the behavior has been previously reinforced.

In addition to establishing and maintaining headbanging in pigeons, Layng et al. (1999) extinguished and differentially reinforced the behavior. The results indicated that when extinguished, the resulting pattern of responding was characteristic of an extinction procedure (i.e., an extinction burst followed by a decline in responding). While headbanging was under extinction, an alternative behavior, key-pecking, was reinforced. Under these conditions, some instances of headbanging recurred. When headbanging
was occasionally reinforced (i.e., the first headbang in a session was reinforced, but the behavior was under extinction for the duration of the session), the rate of headbanging remained stable or increased. From this study, the difficulties that are faced when trying to provide treatments that will eliminate SIB are evident.

As indicated earlier, behavioral treatments have been shown to be effective in reducing SIB; however, there is no single treatment that is effective in treating all cases of SIB. Even when treatments are effective in reducing SIB, completely eliminating this behavior is very difficult. In a random sample of behavioral treatment studies from 1995 to 2000, SIB was completely eliminated in only 15.8% of cases (DeLeon et al., 2002). Even after successful treatment to reduce SIB, the problem behavior can reappear. Lerman et al. (1994) found that a patient whose SIB had been successful suppressed, recurred after the treatment procedure resulted in the development of a new conditioned reinforcer.

In addition to its possible implications in an applied setting, the current set of experiments may strengthen the use of pigeons as a behavioral model for SIB, which has previously only been used by Layng et al. (1999). As mentioned earlier, traditionally, animal models of aberrant behaviors, such as SIB, have been induced by extreme external environment situations, such as monkeys reared in social isolation (e.g., Levison, 1970; Mitchell, 1979; Sackett et al., 1981), or drug-induced (i.e., pemoline) in rodents (e.g., King, 2002; King et al., 1998; Muehlmann et al., 2008). Other animal models of behavior have shown that animals can respond discriminatively in the absence of a primary reinforcer (e.g., food). Epstein, Lanza, and Skinner (1980) showed that two pigeons could “communicate symbolically,” but correct responses were rewarded with
food. Taking the same social communication paradigm, Lubinski and MacCorquodale (1984) demonstrated that symbolic communication could be maintained in pigeons that were not food or water deprived, and were not receiving primary reinforcement.

The present study provides another animal model for SIB and demonstrates that headbanging by pigeons can be the product of routine experimental conditioning. Headbanging, which is topographically similar to a human pathological behavior (and is not a normal behavior in pigeons), can be considered a normal and predictable result of contingencies that are maintaining the behavior (Sidman, 1960). This behavior can be established and maintained in ways similar to other behaviors, like key-pecking or treadle-pressing. Additionally, headbanging can be maintained by conditioned reinforcement alone, which occasions a VT schedule of food reinforcement.
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Developmental Psychology, 17(3), 313-318. doi:10.1037/0012-1649.17.3.313


Mental Retardation and Developmental Disabilities Research Reviews. 7, 3-12. doi:10.1002/1098-2779(200102)7:1<3:AID-MRDD1002>3.0.CO;2-


The current version of the program is set up for shaping headbanging, and then imposing CRF and VI schedules on headbanging under white houselights. The total session duration currently is set at 30 minutes.

**INPUTS**
^HDBG = 3

**OUTPUTS**
^FEEDER = 3
^HOUSELIGHT = 4

DISKFORMAT = 10.2
DISKOPTIONS = FULLHEADERS

**DEFINED VARIABLES**
\(C()\) = Array for irt's on LKEY and RKEY
\(I\) = Subscript for array \(C\)
\(A\) = TOTAL HEADBANGING RESPONSES
\(B\) = TOTAL REINFORCERS FOR HEADBANGING

**TIMERS FOR SCHEDULES AND SESSION**
\(N\) = SESSION CLOCK
\(T\) = Used to increment counts at 0.1" intervals for irt's
\(U\) = SCHEDULE VALUE FOR HEADBANGING

**Z-PULSES USED IN THIS PROCEDURE**
\(Z1\) = Signal for marking HDBG RF on cumulative record

PRINTORIENTATION=PORTRAIT
PRINTCOLUMNNS = 6
PRINTOPTIONS = FULLHEADERS, NOFORMFEEDS

**ARRAY FOR CUMULATIVE RECORD DATA**
DIM C = 9500

**LISTS FOR GENERATING ALTERNATIVE CONC SCHEDULES FOR VI-30s**
LIST U = 1,3,5,7,9,11,13,15,17,19,21,23,24,25,27,29,31,33,35,37,39,41,43,45,47,49,51,53,55,57,59
\(\text{mean} = 30\)
MAIN PROCEDURE

S.S.1. Main logic for VI

S1, #START: ON^HOUSELIGHT; RANDD X = U --- S2
S2, .01": SETX = X*1" --- S3 \converts time into WMPC clock ticks
S3, X#T: --- S4
S4, #R^HDBG: OFF^HOUSELIGHT; ADD B; SHOW 2, LRf, B;
   ON^FEEDER, Z1 --- S5
S5, 2": OFF^FEEDER, ON^HOUSELIGHT; RANDD X = U --- S2

Response Counters & Screen Update

S.S.2.

S1, #START: SHOW 1, LKEY, A, 2, LRf, D, 3, RKEY, B, 4, RRf, E --- Sx
S.S.3.

S1, #R^HDBG: ADD A; SHOW 1, LKEY, A --- S1

Collect irt and reinforcement time codes that can be
read by the SoftCr cumulative recorder program.

S.S.4. Increment time "T" with resolution 0.1 seconds

S1, #START: --- S2
S2, 0.1": ADD T --- Sx

S.S.5. Enter each HDBG response into array C.

S1, #START: SET C(I) = -987.987 --- S2
S2, #R^HDBG: SET C(I) = T + 0.1, I = I + 1;
   IF I = 9499 [TrueArrayFull, @FalseContinue]
   @TrueArrayFull: --- S1
   @FalseCont: SET C(I) = -987.987 --- Sx

Last revised: 13.iv.08
S.S.6, \ Set "Pip" code for HDBG reinforcement.
    \ Since reinforcement occurs at the same time
    \ as the response that delivered the reward, the
    \ incremental time value is zero. For absolute
    \ time values, the code "SET C(I) = .2" has been
    \ changed to "SET C(I) = T + .2."
S1,
   #START: ---> S2
S2,
    #Z1: SET C(I) = T + .2; ADD I;
        IF I = 9500 [@[TrueArrayFull, @[FalseContinue]
        @TrueArrayFull: ---> S1
        @FalseCont: SET C(I) = -987.987 ---> SX

\********************************
|     SESSION TIMER
\********************************
S.S.7,
S1,
   #START: SHOW 5, SESS_TIME, N/60 ---> S2
S2,
   30': SET C(I) = T + .3; ADD I;
   SET C(I) = T + .31; ADD I; SET C(I) = -987.987 ---> STOPABORT

\**********************
|   END SESSION
\**********************
S.S.18,
S1,
   #START: ---> S2
S2,
   30': SET C(I) = T + .3; ADD I;
   SET C(I) = T + .31; ADD I; SET C(I) = -987.987 ---> STOPABORT

\HDBG1:  MED-PC PROGRAM FOR SHAPING HEADBANGING UNDER CRF & VI
\LAST REVISED:  13.iv.08

Last revised: 13.iv.08
The current version of the program imposes a VT schedule, and records the operant level of headbanging, under red houselights. The total session duration currently is set at 30 minutes.

**INPUTS**
- HDBG = 3

**OUTPUTS**
- REDLIGHTS = 2
- FEEDER = 3
- HOUSELIGHT = 4

DISKFORMAT = 10.2
DISKOPTIONS = FULLHEADERS

**DEFINED VARIABLES**
- C() = Array for irt's on HDBG grid
- I = Subscript for array C
- A = TOTAL HEADBANGING RESPONSES

**TIMERS FOR SCHEDULES AND SESSION**
- N = SESSION CLOCK
- T = Used to increment counts at 0.1" intervals for irt's
- U = VT SCHEDULE VALUE

**Z-PULSES USED IN THIS PROCEDURE**
- Z1 = Signal for marking HDBG Rf on cumulative record

PRINTORIENTATION=PORTRAIT
PRINTCOLUMNS = 6
PRINTOPTIONS = FULLHEADERS, NOFORMFEEDS

**ARRAY FOR CUMULATIVE RECORD DATA**
DIM C = 9500

**LISTS FOR GENERATING VT SCHEDULES**
LIST U = 1,3,5,7,9,11,13,15,17,19,21,23,24,27,29,31,33,35,37,39,41,43,45,47,49,51,53,55,57,59
\mean = 30sec
MAIN PROCEDURE

S.S.1, Main logic for VT

S1, #START: ON^HOUSELIGHT; ON^REDLIGHTS; RANDD X=U ---> S2
S2, .01": SETX=X*1" ---> S3 \converts time into WMPC clock ticks
S3, X#T: OFF^HOUSELIGHT; OFF^REDLIGHTS; ON^FEEDER; SETX=9000;
ADD B; SHOW 2,R[I,B,Z] ---> S4
S4, 2": OFF^FEEDER; ON^HOUSELIGHT, ON^REDLIGHTS;
RANDD X = U ---> S2

S.S.3, Response Counters & Screen Update

S5, #START: SHOW 1,HDBG,A, 2,Rf,D ---> SX
S6, #R^HDBG: ADD A; SHOW 1,HDBG,A ---> S1

S.S.4, Collect irt and reinforcement time codes

S5, \Increment time "T" with resolution 0.1 seconds
S1, #START: ---> S2
S2, 0.1": ADD T ---> SX

S6, \Enter each HDBG response into array C.

Last revised: 2.xi.09
@TrueArrayFull: ---> S1
@FalseCont: SET C(I) = -987.987 ---> SX

S.S.7, \* Set "Pip" code for reinforcement under VT.
\* Since reinforcement occurs at the same time
\* as the response that delivered the reward, the
\* incremental time value is zero. For absolute
\* time values, the code "SET C(I) = .2" has been
\* changed to "SET C(I) = T + .2".
S1,
    #START: ---> S2
S2,
    #Z1: SET C(I) = T + .2; ADD I;
    IF I = 9500 [@TrueArrayFull,@FalseContinue]
    @TrueArrayFull: ---> S1
    @FalseContinue: SET C(I) = -987.987 ---> SX

******************************************************************************
          SESSION TIMER
******************************************************************************
S.S.8,
S1,
    #START:SHOW 5,SESS_TIME,N/60 ---> S2
S2,
    1";ADD N;SHOW 5,SESS_TIME,N/60 ---> SX
******************************************************************************
          END SESSION
******************************************************************************
S.S.9,
S1,
    #START: ---> S2
S2,
    30": SET C(I) = T + .3;ADD I;
    SET C(I) = T + .31;ADD I;SET C(I) = -987.987 ---> STOPABORT

VT1: MED-PC PROGRAM FOR VT & OPERANT LEVEL OF HEADBANGING
\*LAST REVISED: 2.xi.09

Last revised: 2.xi.09
MULTIPLE VT/EXT PROGRAM FOR MED-PC
FILENAME, MULVTEX8.MPC
DATE LAST REVISED: 8.ii.10

The current version of the program is set up for a Multiple VT 20-sec:EXT schedule, with the keylights alternating on and off every 10 minutes when the schedules are reversed. The total session duration currently is set at 40 minutes, with 10 min phase changes.

INPUTS
^HDBG = 3

OUTPUTS
^KEYLIGHT1 = 1
^KEYLIGHT2 = 2
^FEEDER = 3
^HOUSELIGHT = 4
DISKFORMAT = 10.2
DISKOPTIONS = FULLHEADERS

DEFINED VARIABLES
\C() = Array for HDBG irt's
\I = Subscript for array C
\A = TOTAL HDBG RESPONSES
\B = TOTAL HDBG REINFORCERS

CONDITIONAL COUNTERS FOR HDBG
\H = REINFORCERS UNDER VT, HOUSELIGHT & KEYLIGHTS
\J = HDBG RESPONSES UNDER EXT

TIMERS FOR SCHEDULES AND SESSION
\M = PHASE FLAGS
\N = SESSION CLOCK
\T = Used to increment counts at 0.1" intervals for irt's
\U = VT SCHEDULE VALUE
\V = EXT SCHEDULE VALUE

Z-PULSES USED IN THIS PROCEDURE
\Z1 = Signal for marking Rf on cumulative record
ARRAY FOR CUMULATIVE RECORD DATA
DIM C = 9500

LISTS FOR GENERATING ALTERNATIVE SCHEDULES FOR MULT[(VI-30s) houselights & keylights:(EXT)houselights only]
LIST U = 1,3,5,7,9,11,13,15,17,19,21,23,24,27,29,31,33,35,37,39,41,43,45,47,49,51,53,55,57,59
\mean = 30
LIST V = 5000,6000 \EXT

***********************
 \ MAIN PROCEDURE
***********************
S.S.1, \Main logic for VT
S1,
#START:SET M=1;ON^HOUSELIGHT;ON^KEYLIGHT1;
ON^KEYLIGHT2;RANDD X=U ---> S2
S2,
,01";SETX=X*1" --->S3 \converts time into WMPC clock ticks
S3,
X#T:OFF^KEYLIGHT1;OFF^KEYLIGHT2;OFF^HOUSELIGHT;ADD B;
SHOW 2;Food deliveries,B;ON^FEEDER;Z1 ---> S4
S4,
2":OFF^FEEDER;ON^HOUSELIGHT;IF (M=1) OR (M=3) [@TRUE,@FALSE]
@TRUE:ON^KEYLIGHT1;ON^KEYLIGHT2;RANDD X = U ---> S2
@FALSE:RANDD X=V ---> SX

***********************
 \ Response Counters & Screen Update
***********************
S.S.3,
S1,
#START:SHOW 1,HDBG,A, 2,Rf,D ---> SX
S.S.4,
S1,
#R^HDBG:ADD A:SHOW 1,HDBG,A,SETY=Y+3;\COD clock
IF (M=1) OR (M=3) [@TRUE,@FALSE]
@TRUE:ADD G --->S1
@FALSE:ADD J --->S1

Last revised:  8.ii.10
Collect irt and reinforcement time codes that can be read by the SoftCr cumulative recorder program.

S.S.6, \ Increment time "T" with resolution 0.1 seconds
S1,
  #START: ---> S2
S2,
  0.1*: ADD T ---> SX

S.S.7, \ Enters each HDBBG response into array C.
\ For absolute or cumulative values the code, "T = 0.1" has been deleted from S2.
S1,
  #START: SET C(I)= -987.987 ---> S2
S2,
  #R^HDBG: SET C(I)= T+0.1, I = I+1;
  IF I = 9499 [@TrueArrayFull,@FalseContinue]
    @TrueArrayFull: ---> S1
    @FalseCont: SET C(I) = -987.987 ---> SX

S.S.8, \ Sets "Pip" code for food reinforcement. Since reinforcement occurs at the same time as the response that delivered the reward, the incremental time value is zero. For absolute time values, the code, "SET C(I) = .2" has been changed to "SET C(I) = T + .2.
S1,
  #START: ---> S2
S2,
  #Z1: SET C(I) = T + .2; ADD I;
  IF I = 9500 [@TrueArrayFull,@FalseContinue]
    @TrueArrayFull: ---> S1
    @FalseCont: SET C(I) = -987.987 ---> SX

SESSION TIMER & PHASE TAGS

S.S.11, \ Sets phase flags
S1,
  #START:SHOW 5,SESS_TIME,N/60---->S2
S2,
  1":ADD N;SHOW 5,SESS_TIME,N/60;
  IF N/60<10 [@TRUE,@FALSE]
    @TRUE:--->SX
    @FALSE:IF (N/60)<20 [@2TRUE,@2FALSE]
      @2TRUE:SET M=2--->SX
      @2FALSE:IF (N/60)<30 [@3TRUE,@3FALSE]

Last revised: 8.ii.10
@3TRUE: SET M=3 ---> SX
@3FALSE: SET M=4 ---> SX

S.S.12, These lines of code reset the CRs at the ends of phases
S1, 1": IF N/60=10 [@TRUE, @FALSE]
    @TRUE: SET C(I) = T + .3; ADD I ---> SX
    @FALSE: ---> SX

S.S.13,
S1, 1": IF N/60=20 [@TRUE, @FALSE]
    @TRUE: SET C(I) = T + .3; ADD I ---> SX
    @FALSE: ---> SX

S.S.14,
S1, 1": IF N/60=30 [@TRUE, @FALSE]
    @TRUE: SET C(I) = T + .3; ADD I ---> SX
    @FALSE: ---> SX

S.S.15,
S1, 1": IF N/60=10 [@TRUE, @FALSE]
    @TRUE: SET C(I) = T + .31; ADD I ---> SX
    @FALSE: ---> SX

S.S.16,
S1, 1": IF N/60=20 [@TRUE, @FALSE]
    @TRUE: SET C(I) = T + .31; ADD I ---> SX
    @FALSE: ---> SX

S.S.17,
S1, 1": IF N/60=30 [@TRUE, @FALSE]
    @TRUE: SET C(I) = T + .31; ADD I ---> SX
    @FALSE: ---> SX

\END SESSION
***************

S.S.18,
S1, #START: ---> S2
S2, 40: SET C(I) = T + .3; ADD I;
    SET C(I) = T + .31; ADD I; SET C(I) = -.987.987 ---> STOPABORT

***************
MEMORANDUM

May 5, 2008

TO: Dr. Paul Andronis
   Department of Psychology

FROM: Cynthia A. Prosen, Ph.D.
      Dean of Graduate Studies & Research

RE: Application to use Vertebrate Animals
    Application # 1ACU-C 097
    Approval Period: 2/1/2008-Continuing

The Institutional Animal Care and Use Committee have approved your application to use vertebrate animals in research, "An experimental analysis of headbanging by pigeons".

If you have any questions, please contact me.

kim
MEMORANDUM

January 29, 2010

TO: Dr. Paul Andronis
Allison Hahn
Department of Psychology

FROM: Cynthia A. Prosen, Ph.D.
Dean of Graduate Studies & Research

RE: Application to use Vertebrate Animals
Application # IACUC 097
Approval Period: 01/29/2010-06/01/2010

The Institutional Animal Care and Use Committee have approved your extension “An experimental analysis of headbanging by pigeons”.

If you have any questions, please contact me.

kjm