Effects of Several Fixed-Ratio Schedules of Reinforcement and of Extinction upon Temporalis and Masseter Muscle Contractions in Humans

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EFFECTS OF SEVERAL FIXED-RATIO SCHEDULES
OF REINFORCEMENT AND OF EXTINCTION UPON
TEMPORALIS AND MASSETER MUSCLE CONTRACTIONS IN HUMANS

by

Gregory E. Pierce

A Thesis
Submitted to the
Faculty of The Graduate College
in partial fulfillment
of the
Degree of Master of Arts

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I would like to thank Dr. Ronald Hutchinson, Dr. Malcolm Robertson, and Dr. Christopher Koronakos for their guidance and encouragement in this lengthy experiment. I am also indebted to the Research Department staff at Fort Custer State Home for their cooperation. I would particularly like to thank Nancy Hunter for preparing the figures, Stephen Betteridge for many helpful suggestions and for editing the final manuscript, Edward Hallin for technical assistance, Nancy Murray for acting as receptionist and bookkeeper, and Grace Emley for assistance in development of the subject recruitment procedure. Finally, I am grateful to Dorothy Graham for typing many drafts, including the final one.

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Gregory Earl Pierce
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REINFORCEMENT AND OF EXTINCTION UPON TEMPORALIS
AND MASSETER MUSCLE CONTRACTIONS IN HUMANS.

Western Michigan University, M.A., 1971
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INTRODUCTION

Aggressive behavior has been elicited by a variety of noxious stimuli. Electric shock and intense heat produce stereotyped fighting postures in paired rats (Ulrich & Azrin, 1962). Electric shock also elicits biting in rats (Azrin, Rubin, & Hutchinson, 1968), and either shock or a physical blow evokes biting in squirrel monkeys (Azrin, Hutchinson, & Sallery, 1964; Azrin, Hake, & Hutchinson, 1965).

Aggressive behavior has also been produced by high fixed-ratio schedules of positive reinforcement, and by subsequent extinction. Pigeons have been observed to peck a target pigeon at the onset of extinction after food reinforcement of a key-pecking response (Azrin, Hutchinson, & Hake, 1966; Knutson, 1970) and as a function of fixed-ratio schedules of reinforcement (Gentry, 1968; Cherek & Pickens, 1970). Squirrel monkeys bite a rubber hose during high fixed-ratio schedules of food reinforcement, and at the onset of extinction from low fixed-ratio schedules of food reinforcement (Hutchinson, Azrin, & Hunt, 1968). More recently, humans have demonstrated preference, during periods of extinction, for a punching response over a button-pushing response to avoid or escape a loud tone (Kelly & Hake, 1970).

Bruxism, or non-functional teeth grinding, is a problem of considerable concern to dentists. Estimates based on verbal reports conservatively place the incidence of nocturnal bruxism in
two populations at 5% and 15%, respectively (Reding, Rubright, & Zimmerman, 1966). The etiology of bruxism is generally viewed as a combination of occlusal interferences and psychic tension (Ramfjord & Ash, 1966). A higher level of frustration and anxiety has been found in bruxists than in non-bruxists (Thaller, Rosen, & Saltzman, 1967; Molin & Levi, 1966). Hollingworth (1939) suggests that chewing may even be a useful technique of relaxation which releases surplus energy.

Electromyographic (EMG) studies have shown an increase in temporalis and masseter muscle activity during periods of emotional stress (Perry, Lammie, Main, & Teuscher, 1960; Yemm, 1969). The EMG activity of the temporalis and masseter muscles increases as a direct function of bite force (Hutchinson & Pierce, 1971; Ahlgren & Wall, 1970). Both of these muscles are active during biting in eccentric relation, while only the masseter is active during biting in concentric relation (Hutchinson & Pierce, 1971). By recording from both of these muscle groups, it is thus possible to distinguish between these two types of activity.

The purpose of this experiment was to determine the applicability to humans of previous findings on ratio- and extinction-induced biting or jaw clenching. EMG activity from the temporalis and masseter muscles was used as an unobtrusive measure of biting incidence and force. A second objective was to determine any differential activity of these two muscles under the experimental conditions.
Establishment of a parallel between the causes of aggressive behavior in animals and causes of jaw clenching in humans would support the latter as a potentially valid measure of aggressivity in humans and thus a worthwhile object of further evaluation.
METHOD

Subjects

Five normal males 22 to 42 years old served as subjects. Two subjects heard about the need for paid subjects by word of mouth, and the other three were recruited by notices placed on various bulletin boards around the Psychology Department of Western Michigan University. Four of the subjects were students and the other (S-1) was a teacher taking a summer course. When a potential subject called, he was informed that the purpose of the experiment was to "measure electrical activity from the head as a function of a simple manual task", and that to accomplish this is would be necessary to attach a number of electrodes to the head. It was explained that some of these electrodes were very fine needles which would be inserted under the skin, but that because they were so fine they would cause no pain. It was explained that the experiment would probably last several weeks. It was further explained when subjects S-1, S-3, and S-5 were recruited that payment would be based on the subject's performance, but should average $3.00 to $4.00 per session, plus $1.00 per session to be added to a "bonus fund" payable upon completion of the experiment. Subjects S-2 and S-4 were recruited after it had been found necessary to double the original amounts to successfully recruit and retain subjects, and they were therefore told that the amounts would average $6.00 to $8.00 per day plus $2.00 to be added to the "bonus fund". If the
potential subject was still interested, he was then informed that a medical examination at a local clinic would be obtained at no cost to him, and that he should fill out a "Medical History Form". A copy of this form is included in Appendix A.

After the subject filled out the form, he was interviewed by the experimenter. During the course of the interview, potential subjects were informed that some transient side-effects, such as temporary soreness of electrode sites, were possible. It was explained that incomplete data were useless to the experimenter and that while the subject would be free to withdraw from the experiment at any time, it was hoped that he would complete it. All subjects affirmed their desire to cooperate in this respect.

In all cases, it was determined that there were no abnormalities which would interfere with the experiment. Each potential subject was questioned as to use of any drugs, legitimately or otherwise. All answers were negative, except that S-3 took vitamin pills and S-4 took 100 mg of Zyloprin (allopurinol) every morning for arthritis. Only one subject (S-4) had participated in any previous experiment and it, from his description, was stimulus discrimination experiment. All subjects were questioned about any background in Psychology. Backgrounds ranged from none to only one or two introductory courses which, for the purposes of this study, were considered naive.

No potential subjects were eliminated by either the interview or the subsequent medical examination. Subjects were scheduled to
begin the experiment as soon as possible after receiving the results of the medical examinations, all of which were negative with regard to clinical abnormalities or pathologies.

Two of the subjects (S—2 and S—4) shared transportation and were scheduled at subsequent times. Part way through the experiment (Session 32) S—5 reported his doctor had prescribed Serax, a tranquilizer (oxazepam, 15 mg 4 times daily as required). Upon debriefing at the end of the experiment, S—3 admitted the use of dextro-amphetamine once during the period of the experiment and the session during which he was on amphetamine (Session 18) was eliminated from analysis. S—2 admitted the occasional weekend use of marijuana, but stated he was never under its influence during a session.

Apparatus

The test chamber was electrostatically shielded with 1/16-inch mesh bronze screen covered by sound-attenuating acoustical tile on the walls and ceiling and carpeting on the floor. It was 114-1/2 inches high, 75 inches long, and 55 inches wide. The room was flat-white with glossy-black trim. The single door was 31-1/4 inches wide and 78-1/2 inches high, and was held closed by a spring. In the same wall as the door was a 25 x 19-inch opening filled with standard 19-inch rack panels for cabling feedthrough and masking-noise speaker mounting. The bottom of the panel was 48-1/2 inches from the floor. White noise at 68 db SPL was supplied by a Grason-Stadler model 901B white noise generator through two Jensen 5P57A
speakers. General chamber illumination was provided by a shielded 100-watt light bulb above the door. The chamber contained a standard wall-mounted thermometer 54 inches from the floor and in plain view. Other than leaving the door open between sessions and turning on a 10-inch fan directed at the doorway, there was no provision for ventilation of the room. Chamber temperatures during sessions ranged from 76° to 96°F, depending upon ambient weather.

The experimental console was covered with two coats of gray paint for insulation to reduce any shock hazard. Using the differential input of a Tektronix model 502A oscilloscope, no voltage in excess of a few millivolts could be detected between the console and any electrode terminal or between any of the electrode terminals themselves. The console was 23-3/4 inches wide, 22 inches deep, and 50 inches high, and faced the long dimension of the chamber (see Figures 1 and 2). The upper front was a 17-1/2-inch high x 19-inch wide sloping intelligence panel. Located 4-1/2 inches from the top of the panel and 2-1/2 inches from the left side was an amber light which illuminated only when the subject pressed the red intercom button located 3 inches below the light. The button was marked "USE ONLY IF NECESSARY". The intercom was designed to monitor the subject's verbal behavior without his knowledge. Located 4-1/2 inches from the top of the panel and 2-1/2 inches from the right side was a red light which came on and remained on until it was reset by the experimenter when a black button, called the "emergency call system", located 3 inches below it was pressed. This button was also marked "USE ONLY IF NECESSARY". Pressing this
button also turned on red lights in the adjacent room where the experimenter was and over the corridor door to that room, and activated a sound alert system consisting of four Mallory SC-628 SonalertS. This system was designed so that, in the event of a power failure, the battery-powered sound system would be triggered automatically. A green light, marked "ON", was located 1-1/2 inches from the top of the panel and 2-1/2 inches from the right side.

Central to the panel was an 8-inch round cutout for a speaker. Two Jensen P5X7V8 5 x 7-inch speakers inside the console gave the illusion that the speaker directly behind the 8-inch cutout was the intercom speaker. Painted 5/16-inch galvanized mesh behind a fine nylon mesh served as the grill. Centered below the cutout was a four-digit Sodeco counter with electrical reset. Centered below the counter was a 2-1/4-inch diameter black microswitch, Model 2PH1, which served as the manipulandum. This switch required a force of 14.7 Newtons and an excursion of about 5/32-inch to close the contacts. It was not necessary for the switch to return the full excursion in order to open the contacts. A red light for response feedback was mounted by the manipulandum, 4-5/8 inches from the left edge of the panel. Inside the console was a 28 VDC relay (Potter and Brumfield KRP-11D) which made an audible click whenever the manipulandum contacts closed. On the back of the console was a dummy switch, 2-1/4 inches from the top and 2-1/2 inches from the right side of the console. This switch was inaccessible to the subject during the session. All electrical connections to the console were made through the floor beneath it and were out of
sight of the subject. The console was entirely enclosed by metal and was grounded to the electrostatic shield of the room.

The console was controlled by a solid-state programmer in the adjacent room. Responses on the manipulandum were recorded on a Gerbrands Model Harvard C-3 cumulative recorder and on Sodeco counters.

A six-channel Grass Model 5 polygraph located in the adjacent room was used to record the data. Two channels utilized Model 5P5 EEG preamplifiers for recording the EMG data directly and two channels employed 5P3 EMG preamplifiers for recording the integrated muscle potentials. The 5P3 preamplifier integrators had charge and discharge time constants of 0.2 seconds. The event pen recorded two event-marker circuits which were combined so that an upward deflection of the event pen indicated a response on the manipulandum and a downward deflection indicated the addition of a reinforcement count on the Sodeco counter on the console. The fifth and sixth polygraph channels were unused. A Model EB24 electrode board was mounted on the back of the subject's chair and the cable from it passed through a slot in the feedthrough panel to the 5ES24 electrode panel on the polygraph.

Procedure

All subjects were run daily, excluding most weekends. Exceptions were S-1, who was out of town for an extended period to attend to family matters, and S-5, who served a 10-day jail term during the course of the experiment. Sessions were scheduled every
hour. Usually there was a waiting period ranging up to about a half hour from the arrival of the subject until the beginning of the experimental procedure. Upon arrival at the laboratory, the subject was escorted to a waiting room supplied with popular magazines and a restroom.

The halls and rooms to which the subjects had access were stripped of any materials which might suggest the objectives of the research being conducted. Exceptions were a relevant article in the *Kalamazoo Gazette* (Mason, 1970), which was inadvertently posted on a bulletin board for a brief period, and a grant proposal on the secretary's bulletin board entitled "The Development of Sustained Attack Behavior". Subject S-1 saw the latter and asked the experimenter whether "that" could have anything to do with the present project. The experimenter replied that the work had to do with the rats undergoing surgery in other rooms in the laboratory.

Two subjects (S-2 and S-4) read the Gazette article before their 28th sessions. The article appeared after all the data had been collected from S-1 and S-3, and only three sessions before S-5 was terminated. Subject S-5 indicated he had not seen the article.

The pertinent part of the article read:

"Among some of the projects being conducted at the Custer State Home laboratory is the study of stress in humans.

"Stress is a condition which can be induced upon humans. Its range of results can produce such things as migraine headaches or commission of murder.

"The study of drugs that reduce or increase aggressive and other emotional tendencies, and electrical energy within the brain as related to seizures such as epilepsy..."
are other kinds of projects taking place, the
director said."

In spite of exposure to these materials, no subject was able to
guess the true objectives of the experiment, even with considerable
encouragement to speculate during a debriefing which followed the
last session.

Prior to each session, the subject was called from the waiting
room and seated where the necessary preparation materials were
available. Next the subject was required to sign a "Consent to Ex­
perimental Procedure" form, a copy of which is included in Appendix
B. The subject was then required to put on a lab jacket. On hot
days the subject was allowed to take off his shirt first. Watches
and jewelry were removed with the explanation that they would inter­
fere with the recording procedure. Glasses, if worn, were tempo­
arily removed to facilitate preparation.

During preparation, a Grass E5S silver cup electrode filled
with Grass Electrode Cream was first applied to the tip of the nose
and secured using three short pieces of Dermicel surgical tape.
Grass E34S ear clip assemblies containing E4S flat silver discs
filled with electrode cream were then attached to each ear lobe.
Four Grass E2B platinum alloy subdermal electrodes were then in­
serted; one in the vertex (the center of the top of the head), one
about 3/4-inch above the occipital lobe, and one each in the central
area of the right and left temporalis muscles. At this point, a
length of elastic bandage was wrapped around the head, covering and
providing strain relief for the occipital and temporalis electrodes.
The subject was asked whether the bandage was too tight, and adjustments were made as necessary. All electrode leads were then wrapped once around the elastic bandage for further strain relief and brought out and down at the back of the head. Finally, two more subdermal electrodes were inserted into the masseter, even with the bottom of the ear and about 1-1/4 inches in front of it. These electrode leads were secured with one short and two long pieces of surgical tape, then wrapped around the elastic bandage and brought out with the other electrode leads. For some subjects, it was necessary to substitute ordinary adhesive tape in order to satisfactorily secure the masseter electrodes. A short length of surgical tape was wrapped around the electrode lead bundle where it left the bandage. The subject was then asked to bend his chin to his chest, and a loop in the electrode leads, large enough to allow for that movement, was left before wrapping a second point on the electrode-lead bundle with tape and taping that point to the top of the subject's jacket. Figure 3 shows a mock subject prepared in this manner. This method of preparation has proven quite immune to movement artifacts and particularly suitable for active subjects (Hutchinson and Pierce, 1971).

Eye glasses, if worn, were then returned and the subject was led to the experimental chamber and seated at a comfortable distance in front of the console. The 100-watt light over the door was turned on. At the first session, the subject was instructed not to touch any of the buttons on the console until their operation was explained. The electrodes were then plugged into the electrode
board on the back of the chair. The nose, the two ears, the vertex, and the occipital electrodes were electrically connected as the reference electrode. This combination is highly effective in averaging common mode signals, thereby reducing artifacts (Hickey, Woelfel, Stacy, & Rinear, 1958).

The two temporali electrodes were connected to the inputs of one integrating and one direct channel, which were connected in parallel. The two masseter electrodes were connected to the inputs of the remaining two channels (direct and integrating), which were also connected in parallel.

The subject was then instructed:

"This (pointing to the alarm button) is the emergency call system. Pushing this button sets off a loud tone and light outside this room, as well as this (pointing to the alarm light) light here. You should use the call button if you feel you have to leave this room for any reason before the end of the session. Any questions?"

If there were any questions, the instruction was repeated. When there were no further questions, the instructions were continued.

"This (pointing to the intercom button) is the intercom. If you need to ask or tell me something, press and hold this button while you talk. Releasing the button permits you to hear my reply. Please avoid any unnecessary communication until the end of the session. Any questions?"

Again, if there were questions, the instruction was repeated and, when there were no further questions, the instructions were continued. After several days, each of the subjects exhibited irritation at the repetition of these instructions. When this occurred, the first two instructions were abbreviated to, "You understand the intercom and emergency call system?" Upon an affirmative reply,
the instructions were continued. Otherwise, the explanation of the two systems was repeated. The following instruction was then given every session:

"About 15 minutes after I turn this (pointing to console) on, this (pointing to the light labeled "ON") green light will come on. When the light is on, you can press this (pointing to manipulandum) button to get points on this (pointing to counter) counter. For each point, you will get twenty cents (a dime for the early sessions of some subjects) after the session. The light will go out after you get 40 points or it has been on for 20 minutes, whichever comes first. The initial 15 minute delay is required to calibrate the EEG recording equipment. Any questions?"

If there were any questions, the instructions were repeated. When there were no further questions, the experimenter switched the dummy switch and said, "I'll be right outside by the recorder throughout the session in case you need me." The experimenter noted the temperature in the experimental chamber, left and closed the door. The temperature was recorded and all driver amplifier, 1/2-amplitude, high-frequency filters were set to 60 hertz. The 5P5 1/2-amplitude, low-frequency filters were set to 1.5 hertz and the 60-hertz filter was left out of the circuit. The polygraph was then calibrated to a sensitivity of 200 uv/cm on all channels and recording was begun at a chart speed of 10 mm/sec. Five minutes after the door to the chamber was closed, the programmer which controlled the console was turned on. This allowed for the recording of muscle potentials and manipulandum responses for the previous ten minutes, before the "ON" light came on. During this ten-minute period, responses had no effect on the subject's counter, feedback light, or feedback relay.
All subjects were reinforced with points on the counter on various, generally increasing, fixed-ratio schedules of reinforcement. Changes in the ratio requirements, except for extinction probes, were made only between sessions. At least two sessions were run at each ratio requirement employed. All subjects started with a ratio requirement of ten responses. Table 1 identifies the sessions run at each ratio requirement for each subject.

The program initially limited the minimum time between responses to approximately 150 msec. When it was found that this was limiting the subjects' response rates, the minimum time between responses was reduced to approximately 50 msec. The polygraph records indicated that this timing did not limit the subjects' response rates. This change was made after S-1 had been terminated, and is indicated in Figure 5 by a break in the plot of response rates for the other four subjects.

Occasionally, each subject was exposed to unsignalled extinction subsequent to reinforcement during the session. Refer to Table 2 for details. Two subjects (S-2 and S-4) were each exposed to signalled extinction for one session as well (see Table 2). The extinction was signalled by turning off the "ON" light. Before a signalled extinction session, the subject was informed that there had been "some trouble with the machine" and that there was a chance it might shut off for a few minutes in the middle of the session. For one subject (S-4), an extended series of unsignalled extinction sessions without any reinforcement was run. In order not to contaminate the ratio data, most of the extinction probes were run late in
in the experimental series.

After the subject's "ON" light went off, a short sample of EMG data was collected, calibration of the polygraph was rechecked, and all data was put away so the subject would not see it. The door to the experimental chamber was opened, a fan directed at the doorway was turned on, and the subject's electrodes were unplugged from the electrode board. While the subject returned to the preparation chair, the experimenter turned off the 100-watt light in the chamber, and again recorded the chamber temperature. The subject was then cleaned up and required to sign another "Consent to Experimental Procedure" form. A copy of this form is included in Appendix C. Finally, a "PAY AUTHORIZATION" form was filled out which the subject presented to the secretary for cash. A copy of this form is included in Appendix D. For the sessions after the payment rate had been changed, a "2" was pencilled over the $1.00 bonus addition statement on this form. The subject was required to sign a standard receipt for the money he received. In the absence of the secretary, the experimenter paid the subject. The subject was then free to leave for the day.

Data Analysis

In order to convert the analog data from the EMG potentials to digital format, a 60-uv input to the integrator channels was chosen as threshold level. This represents a level which is considerably higher than any noise normally encountered in the system, and which is surpassed by most bursts of EMG activity in the data. Indeed,
60-uv signals occur with only light contact of the teeth (Hutchinson & Pierce, 1971). In order to eliminate movement artifacts, which were typically in the range of 1 to 4 hertz, a minimum frequency of 10 hertz was prerequisite to positive responses. This is well below the normal range of EMG frequencies, which was here about 50 to 100 hertz. Because of the wide difference between EMG and artifact frequencies, borderline frequencies near 10 hertz were seldom observed and the distinction was easily made. The only difficult case was the occasionally simultaneous occurrence of movement artifact and EMG signals. Some judgement then had to be exercised in scoring the data. Both the number of within-criteria responses and the number of half-second intervals during which they occurred were analyzed. Half-second intervals were chosen as an index of duration because they coincided with the 5-mm time divisions on the chart paper.
RESULTS

All subjects developed typical patterns of fixed-ratio responding on the manipulandum. This pattern was characterized by a high rate ranging from nearly 300 to over 500 responses/minute. Further, there were very few post-reinforcement pauses, even at high ratio requirements. Ratio strain, with breaks in the middle of the ratio run, usually developed about the same time that the first post-reinforcement pauses occurred. Figure 4 shows typical cumulative records of responding at various ratios for each subject.

While the response rate increased with increasing ratio size, which is in agreement with previous findings (Hutchinson & Azrin, 1961), the present increase in rate was not necessarily a function of ratio size. The ratios were generally run in ascending order of magnitude, and the effect could merely have been a function of the number of sessions. The one subject (S-4) given a reduction, from FR-600 to FR-50, maintained the higher rate for six sessions at FR-50.

Response rate is plotted as a function of ratio size for all subjects in Figure 5. The second FR-50 series for S-4 is plotted as a separate point. The drop in response rate for this subject at FR-1000 may be attributed to strain. The FR-1000 requirement was instated immediately following the second FR-50 series. After receiving two points on his counter during the first FR-1000 session, S-4 stopped responding. After the session he explained that
"it just wasn't worth it". For the remaining three FR-1000 sessions, he responded for a brief period, but did not emit the first 1,000 responses necessary for reinforcement. When he appeared for the next session, he asked how much longer the experiment was going to take. When told that the experiment might last more than another week and a half, he quit.

Sessions selected for analysis of response rate during inter-reinforcement interval contained a number of short post-reinforcement pauses. The rate of responding was nevertheless nearly constant. This characteristic of fixed-ratio schedules of reinforcement is shown in Figure 6. The sessions were selected for analysis on the basis of the highest frequencies and durations of post-reinforcement pauses. Therefore, the very slight depression in rate at the beginning of the ratio run is evidence of the rarity and brevity of post-reinforcement pauses.

During the sessions selected for analysis, the pauses that did occur were found to occur more frequently at the beginning than at the end of the ratio run. The distribution of pauses longer than 0.4 second in the inter-reinforcement interval is shown in Figure 7. Sessions were also analyzed for trends in the pause frequencies as a function of the number of reinforcements, but no consistent trend was found.

Temporalis contraction frequency increased with increasing ratio requirements for two of the subjects (S-3 and S-5). Masseter contraction frequency increased with increasing ratio requirements
for all subjects except S-2. Temporals and masseter contraction frequencies are plotted as a function of the ratio requirement for all subjects in Figure 8. The duration of temporals contractions increased with increasing ratio requirements for two subjects (S-3 and S-5) and the duration of masseter contractions increased with increasing ratio requirements for three subjects (S-3, S-4, and S-5). The durations of temporals and masseter contractions are plotted as a function of the ratio requirement for all subjects in Figure 9. Since masseter activity alone indicates biting in concentric relation, and both temporals and masseter activity indicates biting in eccentric relation (Hutchinson & Pierce, 1971), it may be concluded that, with increasing ratio requirements, two subjects showed an increase in eccentric biting and that one or two subjects showed an increase in concentric biting. The sharp drop in muscle activity when S-4 stopped responding at FR-1000 suggests that the manual response may be necessary for the increase in muscle activity to occur. It should also be noted there was large variability in the absolute base level of activity among the subjects.

The data were analyzed for differences in muscle activity during the ten-minute recording period before the ratio performance, during the ratio performance, and after the ratio performance. No consistent trend was found.

In the sessions selected for analysis, the proportion of long post-reinforcement pauses was low. In contrast, the probability of
temporalis and masseter contractions occurring during the first tenth of the ratio run increased with increasing post-reinforcement pause durations. The proportion of pauses longer than a given duration and the probability of concurrent temporalis and masseter contractions are plotted together in Figure 10. The data suggest that muscle activity occurs during the post-reinforcement pause, and is more likely with longer pauses. Figure 11 contains records from four subjects who showed temporalis and masseter activity during post-reinforcement pauses. The predominance of jaw activity during these pauses is consistent with the finding of Hutchinson, Azrin, & Hunt (1968), that squirrel monkeys bite most during the post-reinforcement pause and the first part of the ratio run. Analysis of contractions during the inter-reinforcement interval, however, produced no consistent trends.

The response pattern during extinction following reinforcement was typical. After extinction was instated, the subject continued to respond at a high rate for some time. Breaks in the response rate then occurred, and numerous small bursts of responses followed the initial break. Typically, there was a sharp increase in the frequency of temporalis and masseter contractions with the change to extinction from reinforcement on a fixed-ratio schedule. Usually, this increase coincided with the first and subsequent breaks in the manipulandum response rate. After these bursts, EMG activity usually declined to a value less than the FR base rate. This is consistent with the finding that the duration of attack in pigeons is an inverse function of the time since the last reinforcement.
(Azrin, Hutchinson, & Hake, 1966). Concurrent cumulative records of temporalis and masseter contractions and manual responding demonstrate this in Figure 12. Only S-3 showed clear masseter activity without temporalis activity. Subjects S-1, S-2, and S-4 showed EMG activity indicative of biting in both eccentric and concentric relation during extinction. The FR base rate of EMG activity for S-5 was so high that further extinction-induced increases were not evident. The characteristic subsequent decline in rate did occur, however. Figure 13 contains two polygraph records showing a burst of contractions following the first break in the manual response rate during extinction sessions. No consistent trends were found in the two signalled extinction sessions.
## Table 1

Session Numbers at Each Ratio Requirement for Each Subject

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</tr>
<tr>
<td>FR-50</td>
<td>7-8</td>
<td>7-8</td>
<td>8-9*</td>
<td>7-8</td>
<td>9-11</td>
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<td>FR-75</td>
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<td>9-10</td>
<td>10-11</td>
<td>9-10</td>
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<td>19-20</td>
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<td>17-18</td>
<td>18-20***</td>
<td>21-22, 24</td>
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<td>FR-200</td>
<td>19-20</td>
<td>18-19</td>
<td>21-26</td>
<td>18-19</td>
<td>25-26</td>
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<td>21-23</td>
<td>27-33</td>
<td>27-28</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FR-300</td>
<td>20-22**</td>
<td>34-35</td>
<td>20-22**</td>
<td>29-30**</td>
<td></td>
</tr>
<tr>
<td>FR-350</td>
<td>36-38**</td>
<td>39-42</td>
<td>32-41</td>
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</tr>
<tr>
<td>FR-400</td>
<td>23-31</td>
<td>31-37***</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FR-500</td>
<td>39-42</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>FR-600</td>
<td>32-35</td>
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<tr>
<td>Extinction</td>
<td>39-52</td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

* Rate of pay was doubled after Sessions 3, 8, and 7 for S-1, S-3, and S-5, respectively.

** Minimum inter-response time changed with Sessions 22, 38, 22, and 30 for S-2, S-3, S-4, and S-5, respectively.

*** Subject had taken dextroamphetamine Session 18. This session was eliminated from analysis.

**** Subject began taking Serax prior to Session 32.
Table 2

Extinction Sessions

<table>
<thead>
<tr>
<th>Subject</th>
<th>Session Number</th>
<th>FR Schedule at Onset</th>
<th>No. of SR's Before Onset</th>
<th>Elapsed Session Time at Onset</th>
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<tbody>
<tr>
<td>S-1</td>
<td>22</td>
<td>250</td>
<td>4</td>
<td>2'44&quot;</td>
</tr>
<tr>
<td>S-2</td>
<td>28</td>
<td>400</td>
<td>7</td>
<td>5'20&quot;</td>
</tr>
<tr>
<td></td>
<td>30</td>
<td>400</td>
<td>9</td>
<td>7'5&quot;</td>
</tr>
<tr>
<td></td>
<td>35*</td>
<td>600</td>
<td>4 (10)</td>
<td>5'0&quot;</td>
</tr>
<tr>
<td></td>
<td>39-52</td>
<td>**</td>
<td>0</td>
<td>0'0&quot;</td>
</tr>
<tr>
<td>S-3</td>
<td>40</td>
<td>500</td>
<td>5***</td>
<td>6'15&quot;</td>
</tr>
<tr>
<td></td>
<td>41</td>
<td>500</td>
<td>8</td>
<td>8'37&quot;</td>
</tr>
<tr>
<td></td>
<td>42</td>
<td>500</td>
<td>11****</td>
<td>13'52&quot;</td>
</tr>
<tr>
<td>S-4</td>
<td>20</td>
<td>300</td>
<td>5</td>
<td>5'0&quot;</td>
</tr>
<tr>
<td></td>
<td>26</td>
<td>400</td>
<td>9</td>
<td>10'8&quot;</td>
</tr>
<tr>
<td></td>
<td>35*</td>
<td>600</td>
<td>3 (8)</td>
<td>5'0&quot;</td>
</tr>
<tr>
<td>S-5</td>
<td>33</td>
<td>*****</td>
<td>0</td>
<td>0'0&quot;</td>
</tr>
<tr>
<td></td>
<td>36</td>
<td>400</td>
<td>7</td>
<td>5'40&quot;</td>
</tr>
<tr>
<td></td>
<td>37</td>
<td>400</td>
<td>10****</td>
<td>8'0&quot;</td>
</tr>
</tbody>
</table>

* Signalled extinction session. Subject was on indicated ratio for 5 minutes, on extinction for 7 minutes, and then on ratio again. Number in parenthesis indicates total number of SR's.

** Extinction without reinforcement. One point was allowed on Session 42 because counter did not reset properly and stuck between 0 and 1.

*** Six points were allowed because counter improperly reset and was stuck between 5 and 6.

**** Counter was reset to zero at 1'6" after 11 SR's plus 460 responses for S-3, and at 0'45" after 10 SR's plus 370 responses for S-5.

***** Extinction prior to FR-400. 4'57" elapsed and 1,964 responses were emitted before the first reinforcement occurred.
FIGURE 1

Front view of intelligence panel.
FIGURE 2

side view of experimental console, as viewed through doorway to chamber.
FIGURE 3

Mock subject, showing attachment of electrodes.
FIGURE 4

Typical cumulative records of responding on the manipulandum at various ratio requirements for each subject. Pen reset to baseline every 500 responses. Some data are from sessions before the recording circuitry was adjusted to match the high response rates encountered. In this early data, rapid pairs of responses were occasionally recorded as a single response.
Manual response rate as a function of ratio size for each subject. Breaks in the curves are where the recording circuitry was adjusted as described in Figure 4 and the text. The separate data point for S-4 is the response rate at FR-50 after the reversal from FR-600 and reflects data collected after the circuitry adjustment. Data from extinction and immediately following sessions were excluded.
FIGURE 6

Manual response rate during selected sessions as a function of number of responses since last reinforcement. Sessions selected were those having the most frequent and highest duration post-reinforcement pauses.
FIGURE 7

Number of pauses greater than 0.4 seconds (during same sessions selected for Figure 6) as a function of the number of responses since the last reinforcement.
FIGURE 8

Frequency of above-criteria temporalis and masseter contractions as a function of the fixed-ratio requirement. Data from extinction and immediately following sessions were excluded.
Duration of above-criteria temporalis and masseter contractions as a function of the fixed-ratio requirement for each subject. Duration was obtained by dividing the number of half-second intervals per minute during which both criteria were met by two. Data from extinction and immediately following sessions were excluded.
FIGURE 10

Proportion of ratio runs (during the sessions selected for Figure 6) in which a pause greater than a given duration occurred in the first tenth of the ratio run, and the conditional probability of concurrent, above-criteria temporalis and masseter contractions, given the occurrence of a pause in responding on the manipulandum during the first tenth of the ratio greater than a given duration.

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FIGURE 11

Polygraph records for four subjects showing temporalis and masseter EMG activity during post-reinforcement pauses. The post-reinforcement pause shown by S-5 occurred after initial extinction (see Table 2 for details). On each record, the tracings are, from top to bottom: direct temporalis EMG, integrated temporalis EMG, event marker, direct masseter EMG, and integrated masseter EMG. Upward deflections of the event pen indicate responses on the manipulandum and downward deflections indicate reinforcements. Sensitivity on all channels was 200 uv/cm and chart speed was 10 mm/sec.
S-1
FR-300

S-2
FR-75

S-3
FR-300

S-5
FR-400

AFTER INITIAL EXTINCTION

90 SECONDS

200 μV

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FIGURE 12

Cumulative records of temporalis and masseter contractions which met criterion, and of manual responses (button pushes), during an extinction session for each subject. Pen reset to baseline every 500 responses. Cumulative records of temporalis and masseter contractions were generated by playing back the EMG record at recorded speed and manually pressing buttons activating the appropriate cumulative recorder functions as each above-criteria contraction and each reinforcement mark passed a static line across the record.
Polygraph records for two subjects showing temporalis and masseter EMG activity following the first break in the manual response rate during extinction. On each record, the tracings are, from top to bottom: direct temporalis EMG, integrated temporalis EMG, event marker, direct masseter EMG, and integrated masseter EMG. Upward deflections of the event pen indicate responses on the manipulandum. Sensitivity on all channels was 200 uv/cm, and chart speed was 10 mm/sec. For S-2, the arrow indicates completion of the prior ratio requirement following the onset of extinction. For S-1, the record portion shown begins 1,621 responses after onset of extinction.
DISCUSSION

It should be noted that not all subjects demonstrated a clear increase in temporalis and masseter activity with an increase in ratio size and with extinction. This is consistent with previous findings that not all monkeys subjected to intense foot-shock would bite a target object (Azrin, Hutchinson, & Sallery, 1964) and that not all monkeys would bite consistently after a physical blow (Azrin, Hake, & Hutchinson, 1965).

A feature of the EMG method that may contribute to the inconsistent results is that, while it is an unobtrusive measure of jaw clenching, no target object is provided. In measurement of biting in rats, Azrin, Rubin, & Hutchinson (1968) found that a suitable target object, one which the rat would bite and yet not destroy, was a major problem. While a higher base rate of EMG activity would probably result, giving the subject chewing gum might be considered as an addition to the present procedure. Ahlgren & Öwall (1970) found a quantitative relationship between EMG levels and chewing force using gum. It may be that an object between the teeth would strengthen any tendency to clench the jaw, and thus make the measure more sensitive. Gum chewing has been advocated as a method of relaxation (Hollingworth, 1939), indicating that it may be an outlet for tension. Further, bruxism has been successfully treated by the elimination of occlusal interferences (Ramfjord & Ash, 1966); and gum, considered as an artificial occlusal interference, might enhance probabilities of non-functional biting or
A major finding of this experiment was that, while temporalis and masseter activity is most probable during long post-reinforcement pauses, the frequency of post-reinforcement pauses in humans is very low, even at very high ratio requirements. This is consistent with the finding that biting in monkeys occurs primarily during the post-reinforcement pause and the early part of the ratio run (Hutchinson, Azrin, & Hunt, 1968). Weiner (1966) suggests that the post-reinforcement pause characteristic of fixed-ratio performance in animals may not be characteristic in humans. However, the fact that post-reinforcement pauses have been found with fixed-ratio requirements of 10 and 15 responses in one-to-two-year-old infants (Weisberg & Fink, 1966), in retarded adults (Ellis, Barnett, & Pryer, 1960), and in mental patients (Hutchinson & Azrin, 1961) indicates that post-reinforcement pauses can be consistently obtained under some conditions. Thus, if the experiment were modified to make post-reinforcement pauses more frequent, it might be expected that the long pauses would occur at higher ratio requirements and that a stronger and more consistent relationship could be found. One technique might be to require a second response after a stimulus light came on indicating the ratio requirement had been met. In successfully eliciting punching responses during extinction, Kelly & Hake (1970) required the insertion of a penny in a slot in order to receive a nickel. It has been suggested that a brief time-out following reinforcement might be sufficient to generate pauses much longer than the time-out itself (Hutchinson, personal
communication). Sanders (1969) required a three-second period of non-responding, while the magnitude of the reinforcer was displayed, before a count was added to the reinforcement counter. However, no post-reinforcement pauses or ratio-strain up to FR-1000 were found. It may be found that a brief exposure to another schedule of reinforcement, such as a fixed-interval schedule before the fixed-ratio schedule is instituted, would generate the desired pauses. Weiner (1964) has shown that the rate of responding on a fixed-interval schedule of reinforcement in humans is higher after a history of fixed-ratio reinforcement than after a history of differential reinforcement of low rates. Thus, it would be reasonable to believe that there may be interaction between other schedules of reinforcement. Finally, Long (1963) reported successful stimulus control with young children on chained and tandem DRL FR and DRO FR schedules. All of these schedules force a pause in responding following reinforcement. Particularly with a tandem schedule, variable post-reinforcement pauses might be expected, perhaps with the longer pauses occurring at higher ratio requirements.

The subjects who showed positive effects on both ratio- and extinction-induced jaw clenching were about evenly divided between those who demonstrated eccentric and those who demonstrated concentric clenching. The probability of both temporalis and masseter contractions during long post-reinforcement pauses was high. While this would indicate clenching in eccentric relation, the data represented by those long pauses is such a small proportion of the total
data that no conclusion on predominance of either eccentric or concentric clenching is warranted.

The transition from high ratio requirements to extinction may have partially obscured the effect of extinction on the temporalis and masseter muscle activity. The attack found by Azrin, Hutchinson, & Hake (1966) followed continuous reinforcement, and the biting reported by Hutchinson, Azrin, & Hunt (1968) followed fixed-ratio requirements of 2 and 20. Kelly & Hake (1970) found positive results in humans following a fixed-ratio requirement of 200, but the design of that experiment must be born in mind. The ratio requirements prior to extinction in this experiment ranged from 250 to 500.

This experiment has established a parallel between the ratio- and extinction-induced aggression in animals and ratio- and extinction-induced temporalis and masseter muscle activity in humans. If further parallels between the causes of aggressive behavior in animals and the activity of these muscles in humans can be found, they will strongly suggest that temporalis and masseter muscle activity in humans is a valid index of aggressivity. In view of the wide variability noted in the base level of the activity, this EMG technique may provide a tool to distinguish between different individuals and groups on the basis of quantitatively measured aggressivity.
REFERENCES


Hutchinson, R. R. (personal communication).


Hutchinson, R. R. & Pierce, G. E. Jaw clenching in humans: Its measurement, and effects produced by conditions of reinforcement and extinction. (in preparation)


APPENDIX A

Medical History Form
NAME __________________________ AGE _______ SEX _______

ADDRESS __________________________ PHONE _______

DATE OF BIRTH _______ MARITAL STATUS _______

OCCUPATION __________________________

ARE YOU A UNITED STATES CITIZEN? YES_____ NO_____

Medical History:

1. Do you consider yourself to be in good health at the present time?
   yes_______ no_______

2. Have you ever been refused employment, insurance or rejected from
   the armed forces because of your health? yes____ no_____

3. Do you now or have you ever had any of the following illnesses?
   
   - asthma Yes ___ No ___
   - bronchitis ___ ___
   - hay fever ___ ___
   - rheumatic fever ___ ___
   - epilepsy ___ ___
   - tuberculosis ___ ___
   - diabetes ___ ___
   - increased blood pressure ___ ___
   - stomach trouble ___ ___
   - heart trouble ___ ___
   - migraine headache ___ ___
   - serious infections ___ ___
   - skin trouble ___ ___
   - arthritis ___ ___
   - tooth ache ___ ___
   - bleeding gums ___ ___
   - bladder or kidney trouble ___ ___
   - nervous or mental disorder ___ ___
   - infectious mononucleosis ___ ___

4. Do you have any allergies to drugs, foods, animals, plants, insects, dust, etc.?
   yes_______ no ______ If yes, please explain.
5. Are you presently under the care of a physician, psychiatrist or therapist?
   yes_______ no_______

6. Are you presently or have you recently received any medication for any reason (including vitamins, pep pills, diet pills, tranquilizers, etc.)?
   yes_______ no_______

7. Are you on any special diet? yes_______ no_______

8. Has anyone in your family had any of the following illnesses? (grandparents, parents, brothers, sisters, children)

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<tr>
<th>Illness</th>
<th>YES</th>
<th>NO</th>
<th>RELATIONSHIP</th>
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<td>asthma</td>
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<td>hay fever</td>
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<td>epilepsy</td>
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<td></td>
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<td>nervous or mental disorder</td>
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<td>cancer</td>
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<td>heart disease</td>
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<td>severe headache</td>
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<td></td>
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<tr>
<td>high blood pressure</td>
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</table>

9. When was your last physical exam?

10. When did you last have a dental check up?

GENERAL INFORMATION

1. Have you ever taken part in any experimental studies? yes __ no__
   If yes, did these studies involve any of the following:

<table>
<thead>
<tr>
<th>Type of Study</th>
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<th>NO</th>
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<td>ingestion of food substances</td>
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</tr>
<tr>
<td>ingestion or injection of drugs</td>
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<tr>
<td>metabolic tests</td>
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<td>blood or urine tests</td>
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<td>blood pressure recording</td>
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<td>abstinence of any sort</td>
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<td>sleep</td>
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</tbody>
</table>
2. Are you right handed? yes_____ no_____

3. Do you wear any of the following:
   false teeth or bridge YES_____ NO_____
   hearing aid _______ ______
   glasses _______ ______
   braces for teeth _______ ______

4. Have you ever been bothered by claustrophobia? yes_____ no_____

5. Are you currently enrolled in an educational program of any sort?
   yes_________ no_________

6. Please indicate daily or weekly frequency of the following:
   a. sleep (hrs.)
   b. alcohol consumption
   c. exercise (hrs.)
   d. tobacco consumption (cigars, cigarettes, pipe)
   e. chewing gum _____
   f. coffee
   g. tea

7. Do you suffer from headaches? yes_____ no_____
   If yes, what is the frequency of their occurrence?

8. Are you a nail biter or pencil chewer? yes_____ no_____

9. Do you participate actively in sports? yes_____ no_____

Signed _______________________________
Witness ____________________________
Date _______________________________
APPENDIX B

Consent to Experimental Procedure
Consent to Experimental Procedure

I, _________________________________ hereby consent to serve as a volunteer experimental subject for the Research Department of Fort Custer State Home. I have been informed of the experimental procedure and that there may be temporary unpleasant side effects. I understand that I may withdraw at anytime from participation in this research.

Signed __________________________

Witness __________________________

Date __________________________
APPENDIX C

Consent to Experimental Procedure
Consent to Experimental Procedure

I, __________________________ have served as a volunteer experimental subject for the Research Department of Fort Custer State Home. I have been informed of the experimental procedure and that there may be temporary unpleasant side effects. I understand that I may withdraw at anytime from participation in this research. I felt _____, did not feel ______, unpleasant side effects. If so they were

________________________________________

________________________________________

Signed __________________________

Witness __________________________

Date __________________________
APPENDIX D

Pay Authorization
PAY AUTHORIZATION

Please pay ___________________  $___________  for_______
counts. Also add $1.00 to his bonus fund.

Authorized Signature

Date