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OPERANT PROCEDURES AND THE COMATOSE PATIENT

MARY ELINOR BOYLE AND R. DOUGLAS GREER

STATE UNIVERSITY OF NEW YORK COLLEGE AT NEW PALTZ AND
TEACHERS COLLEGE, COLUMBIA UNIVERSITY

Operant procedures were tested on three patients who had been in vegetative coma for 6 months, 10 months, and 38 months. A discrete trial procedure was used to test compliance to verbal requests for three behaviors for each patient, including lateral head movement or finger movement, eye focus or eye squeeze, and mouth movement. The design for each patient consisted of multiple baselines across three behaviors with a withdrawal phase and a reinstatement phase (ABAB) for one behavior. Baseline phases were followed by contingent music phases in which 15-second taped excerpts of patients' preferred music sounded immediately following the emission of targeted behaviors. The contingent music treatment affected all three behaviors for Patient 1, but was less effective for two out of three behaviors for the second and third patients who had been in coma for more extensive periods of time. Results are discussed in terms of the potential contributions of the use of operant assessment and treatment procedures in an area of medicine where they have not been used before.

DESCRIPTORS: coma, behavioral medicine, vegetative coma

"Coma remains one of the most enigmatic and least predictable conditions in clinical medicine" (de la Torre, Trimble, Beard, Hanlon, & Surgeon, 1978, p. 304). The condition may lead to recovery, a vegetative state, or death. Acute coma is conservatively described as a sleeplike state in which "cognitive functions are diminished and the patient is unresponsive to all outside stimuli" (Posner, 1978, p. 218). Those patients who neither die nor recover also remain unresponsive, but may appear awake. "Continuous sleep-like coma almost never lasts more than two to four weeks. . . . After that point, or even before, many seriously brain-injured patients develop a chronically unresponsive state in which they look awake but give little or no evidence of possessing either sentient recognition of the environment or any other cognitive mental content" (Plum & Posner, 1980, p. 3). The diagnosis, *vegetative state,* is appropriate for these individuals because the term "describes behavior, and it is only data about behavior which will always be available . . . in every patient, because such observations are independent of special procedures such as E.E.G. and measures of cerebral bloodflow or cerebral metabolism. This term presumes neither a particular physioanatomical abnormality nor a specific pathological lesion. . . ." (Jennett & Plum, 1972, p. 736).

Standardized procedures have been developed for testing responsiveness of the comatose patient to external stimuli. The Glasgow Coma Scale examines the best eye opening, verbal, and motor responses occurring in given time periods (Habbema, Braakman, & Avezaat, 1979; Teasdale, Murray, Parker, & Jennett, 1979). The Munich Coma Scale uses additive scales to rate susceptibility to stimulation and reactivity (Brinkmann, von Cramon, & Schulz, 1976). Stimulation involves electrical, tactile, acoustic, and optic devices, and reactions are motoric,

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mimic, orientating, or communicative responses. These standardized scales are not widely used, nor do they measure operant responses. The studies reported here were designed to apply the technology of the experimental analysis of behavior to test the responsiveness of comatose patients.

There are several studies dealing with profoundly retarded individuals who were described as vegetative (Brownfield & Keehn, 1966; Fuller, 1949; Rice & McDaniel, 1966; Rice, McDaniel, Stallings, & Gatz, 1967). Coma patients and profoundly retarded individuals are similar in their lack of responses, but their conditioned reinforcers may be different. Dorow (1975) conditioned music stimuli for retarded individuals until the music was as effective as food for reinforcing responses to verbal commands. Rice et al. (1967) found that only primary reinforcers were effective. Without special reinforcement conditioning procedures, only primary reinforcers are viable for many profoundly retarded individuals. However, the comatose patients have had numerous conditioned reinforcers prior to their trauma. Also, primary reinforcers are often difficult to use with comatose patients because of the mechanized life support systems (e.g., oxygen, gastronomy tubes, tracheal tubes, and ventilators) and their tentative and often precarious physical state.

Operant procedures have been used in several fields in medicine, including dentistry, gerontology, internal medicine, neurology, pediatrics, and rehabilitation (Iwata & Becksfort, 1981; Melamed & Siegel, 1980). Biofeedback has been useful in many cases, but the comatose patients cannot rely on the informative aspect of biofeedback and their responses can be overt rather than covert. Additionally, measurements of overt responses are as effective and more practical than measurements of covert responses in predicting prognosis of comatose patients (Bates, Caronna, Cartlidge, Knill-Jones, Levy, Shaw, & Plum, 1977; Jennett & Plum, 1972; Levy, Bates, Caronna, Cartlidge, Knill-Jones, Lapinski, Singer, Shaw, & Plum, 1981).

Music was selected as a contingency for the patients reported here because it seemed suited to the limitations of the patients while simultaneously tapping their potential to be controlled by conditioned reinforcers from their own unique histories. There is an extensive literature on music as a reinforcer for a wide variety of responses, as well as on the variables related to its conditionability (Greer, 1981). In addition, music is unobtrusive, easy to administer, unlikely to produce satiation, and unlikely to create resistance from caretakers, medical personnel, or members of the patients' families.

The question addressed in the experiments is: Can operant procedures be used to assess environmental control of overt responses of comatose patients in a vegetative state?

METHOD

Patients

Three patients were selected because of interest by their relatives and physicians.

Patient 1. The first patient was a 56-yr-old male who was comatose as a result of an accident 6 mo prior to the study. He had severe brain stem injury, a left subdural hematoma, and a right hygroma. A craniotomy for evacuation of the subdural hematoma was performed within 24 h of the onset of coma. Three months prior to the experiment, computerized tomographic (CT) scans showed dilated ventricles which were in midline and low density air in the left occipital region. The patient was transferred to a 200-bed rehabilitation hospital in a suburban area after having been diagnosed as being in a vegetative state.

The patient blinked his eyes infrequently and was reported to have squeezed a hand placed in his hand following verbal directions to do so. Reflex withdrawal of the right extremities and the left upper extremity was produced by pen stimulation. His pupils were isocoric; the response to light was sluggish. Corneal reflexes were present bilaterally. Bilateral Babinski signs

were present. Essential pulmonary functions were maintained by chest physiotherapy and respiratory function was maintained by a tracheal tube and an oxygen supply. Throughout the experiment the patient received Dilantin (400 mg OD), Synthroid (0.1 g OD), Folate (1 mg OD), multivitamins, Bronkosol, and Mucomist for Intermittent Positive Pressure Breathing. Dilantin may produce side effects of lethargy and drowsiness (Govoni & Hayes, 1978).

Patient 2. The second patient was a 31-yr-old female who had been in a persistent vegetative state for 3 yr and 2 mo. She had suffered severe anoxic brain damage as a result of respiratory arrest, a complication of the Guillain Barre Syndrome. Injuries included cortical and probable brain stem damage, spastic quadriplegia, a seizure disorder, and multiple permanent contractures. The electroencephalogram (EEG) taken 13 mo after respiratory arrest showed bilateral cerebral dysfunction with bilateral spike discharges and irritative features. No change was indicated from previous EEG measurements. Loud noises elicited grimacing and jerking responses. Two physicians obtained contradictory pupillary responses to light. Contradictory results were also obtained for corneal responses. Both great toes were partially contracted in plantar flexion and were mute to plantar stimulation. Ordinarily, her mouth remained closed and moved in a chewing/sucking manner; a tracheostomy site had never completely closed. The patient's eyes rarely focused on an individual or object, rather her eyes moved in a continuous roving fashion. She received the following medication throughout the experiment: Dantrium (75 mg QID), and Liquid Dilantin (100 mg TID).

Patient 3. The third patient was a 44-yr-old Hispanic male. He had been in a semi-comatose state for 10 mo as a result of a cerebral vascular accident. The patient had brain stem injury, spastic involvement of all extremities, a seizure disorder, and extremely labile hypertension. Typical blood pressure changes within 1 h included ranges from: 132/80 to 254/166 and 260/180 to 170/118. Staff members had reported that they had seen the patient move his head slightly in the direction of family members' voices and open his eyes. His right extremities were more spastic than his left and with effort the physical therapist could bring his extremities to full extension. During the day the patient had Zimmer splints on his lower extremities and Volar splints on his upper extremities. Bilateral Babinski responses were present. No plantar response was present. The patient received the following medication throughout the experiment: Hygroton (50 mg QD), Liquid Bactrim (10 ml HS), Minipress (3 mg QD), Dilantin (100 ml BID), and Catapres (.4 mg BID). Possible side effects of Minipress, Dilantin, and Catapres were drowsiness and lethargy (*Physicians' Desk Reference,* 1981).

Settings

Patient 1 was in a private room in a 200-bed rehabilitation hospital in a suburban area. Patients 2 and 3 were in private rooms in a 500-bed nursing facility in a suburban area. All sessions occurred in the patients' rooms, except for several sessions for Patients 2 and 3 which occurred in the trainer's office. No differences in response were found between the room and office settings.

Response Definitions and Data Collection Procedures

Patient 1. Three responses were selected based on recommendations of the rehabilitation team: (a) eye squeeze, (b) finger movement, and (c) mouth movement. Each behavior was considered within the patient's repertoire except for finger movements. One eye squeeze consisted of movement of the eyelid in which the upper and lower lids of both eyes squeezed shut and opened in a manner distinctly more exaggerated than a reflexive eye blink. Finger movement consisted of any movement of the fingers of either or both hands. Mouth movement consisted of any movement of the jaw.

The response had to occur within 10 sec after the trainer's verbal request in order to be scored

as an occurrence. Verbal requests and 10-sec intertrial response periods occurred in a discrete trial format. Each session contained 33 trials, 11 trials for each of the three behaviors. The first of the 11 trials was a physically prompted trial, in which the patient's eyelids, fingers, or jaw were/was physically guided through an appropriate response. This trial was not scored. The subsequent 10 trials were not guided or prompted. After the prompted trial and the 10 unprompted trials for a single behavior were completed, the second behavior was treated identically, as subsequently was the third behavior. The order of responses requested was randomly determined for each session. Although the order of blocks of trials was randomized, the serial presentations of behaviors within blocks was maintained throughout with one exception. Session 116 consisted of the presentation of randomized trials to probe for serial order effects. During randomized trials, no prompted trials occurred, and the order of the occurrence of the behavior requested was randomly arranged across 30 trials.

Trials consisted of the following parts: (a) The patient's name was stated; (b) a verbal request was made for the patient to move his fingers, mouth, or eyelids; (c) a 10-sec response period followed immediately after the request (intratrial response period); (d) a 15-sec silence/music interval (intratrial reinforcement period) followed the occurrence of a response or followed the 10-sec intratrial response period; (e) the subsequent trial was initiated. Occurrence of the behavior was scored within the intratrial response period. The trainer used a footpedal to activate a tape recorder containing the observation cues for the 10-sec intratrial response periods. The trainer and reliability observer heard the cues through an earplug. The 15-sec intratrial silence was cued by a stopwatch operated by the trainer or observer.

The patient was introduced to the trainer by the patient's wife prior to the first session. She requested that the patient "do what the therapist asked." The study extended over 12 wk with two sessions 7 days per week. Sessions were separated by 2-4 h and varied in length from 20 to 40 min.

Patient 2. Three behaviors were studied: (a) eye focus, (b) lateral head movement, and (c) mouth opening. None occurred in normal frequencies. Eye focus consisted of the patient's opening her eyes or ceasing to move them about and subsequently fixing her eyes on the trainer's face for a 2-sec count. Lateral head movement consisted of movements of the head to left or right that were clearly not spasms or movements related to breathing. Mouth opening consisted of moving the mandible so that lips parted and tongue or teeth were visible. The data collection procedures were the same as with Patient 1 with two exceptions. First, all successive ninth and tenth sessions were randomized order probes with no physical guidance or prompts. Randomized trials were conducted to assess any possible training order effects. Second, if the patient's eyes were closed for five successive no-response trials, she was shaken until her eyes opened.

Patient 3. The dependent variables were the same as those described for Patient 2. The data collection procedures were the same as those described for Patient 2 except that verbal requests were given in Spanish.

Reliability

Reliability observations were made for 55 of the 140 sessions for Patient 1, for 42 of 79 sessions for Patient 2, and 31 of 65 sessions for Patient 3. The observations were made by a trained observer in the same room with the patient and trainer. For Patient 1, the mean for occurrences plus nonoccurrences was 97% (range: 87% to 100%), for Patient 2, 98% (range: 90% to 100%), for Patient 3, 98% (range: 87% to 100%).

The second reliability index was for occurrences and nonoccurrences for each behavior (10 trials) separately. For Patient 1, the mean was 98% for mouth movement (range: 80% to 100%), 96% for finger movement (range:

80% to 100%), and 98% for eye squeeze (range: 80% to 100%). For Patient 2, the mean was 95% for eye focus (range: 80% to 100%), 99% for lateral head movement (range: 80% to 100%), and 100% for mouth movement. For Patient 3, the mean was 98% for eye focus (range: 90% to 100%), 97% for lateral head movement (range: 87% to 100%), and 99% for mouth opening (range: 90% to 100%).

The third reliability index was for occurrences of behavior only. For Patient 1, the means were: 94% for mouth movement (range: 0% to 100%), 90% for finger movement (range: 0% to 100%), and 91% for eye squeeze (range: 0% to 100%). For Patient 2, the means were: 81% for eye focus (range: 0% to 100%), 98% for lateral head movement (range: 50% to 100%), and 100% for mouth opening. For Patient 3, the means were: 74% for eye focus (range: 0% to 100%), 66% for lateral head movement (range: 0% to 100%), and 89% for mouth opening (range: 67% to 100%). Each occurrence of 0% reliability occurred only once for each behavior and occurred at those sessions in which the observers disagreed on one response.

Design

The design was a multiple baseline across three responses with a withdrawal and reinstatement of contingent music for the behavior with the highest mean. The independent variable was 15-sec excerpts of the patient's preferred music contingent on the emission of a response during the contingent music phases. For Patient 1, one randomized order probe was conducted on session 116. For patients 2 and 3, randomized order probes were conducted every ninth and tenth sessions.

Contingent Music

When the patient emitted a correct response, the trainer activated a tape recorder by a footpedal. This resulted in 15 sec of a musical excerpt that replaced the 15-sec intertrial silence which occurred during baseline and those contingent music trials in which no response occurred. For the contingent music phases, the response for each initial trial was physically guided and resulted in music. After this initial trial, the patient was required to emit the behavior with no physical prompts before receiving the music. The family of each patient chose music for the patient. The music for Patient 1 was "Camelot"; for Patient 2, recordings of the singer Linda Ronstadt; for Patient 3, "Disfrutelo Hasto el Cabo!" by El Gran Combo de Puerto Rico and "Album Homenaje! 30 anos de Victo Pinero: Los Melodicos."

RESULTS

Figures 1, 2, and 3 show the daily means of responses for each behavior. Means are used rather than totals because on some days only one session was conducted, but for most days two sessions were conducted. Daily means accurately reflect per session totals yet do not allow the prolonged length of the studies to interfere with visual comparisons of phases. (Figures for per session totals are available from the second author.)

The mean for eye squeeze (Figure 1) for Patient 1 during baseline was .90 (range: .9 to 1.5) and the mean for the first contingent music phase was 4.7 (range: .5 to 8.5). During baseline 2, the mean was 2.62 (range: 0 to 7). The total for the final day in which contingent music was reinstated for the one session conducted was 9. The baseline mean for finger movement was 1.9 (range: 0 to 5), and the mean for the contingent music phase was 4.6 (range: .5 to 10). The baseline mean for mouth movement was 1.9 (range 0 to 6). During the contingent music phase, the phase mean was 3.8 (range: 0 to 9).

Despite the variability that occurred within the contingent music phases, the music excerpts did raise the emission rates. The variability is not surprising when the precarious medical state of the patient is taken into account. It was difficult to determine the state of wakefulness with this patient, and it was thought that part of the

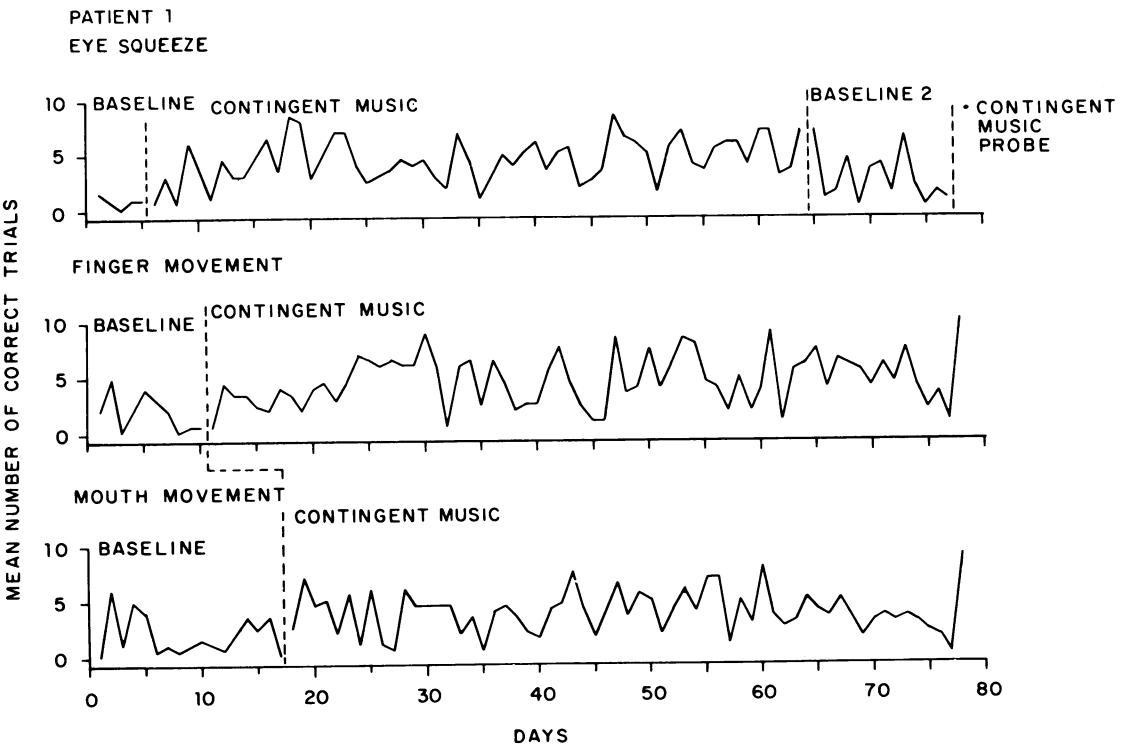

Fig. 1. Daily means of correct trials by Patient 1 for eye squeeze, finger movement, and mouth movement.

variability was attributable to the patient being asleep. In the subsequent experiments, patients were shaken until their eyes opened if there were five consecutive trials with no response and the patient's eyes remained continuously closed.

For Patient 2 (Figure 2) the baseline mean for lateral head movement was .75 (range: 0 to 1). During the contingent music phase, the mean was 2.5 (range: 0 to 6). The baseline mean for eye focus was .5 (range: 0 to 1.5) and the mean for contingent music was 3.2 (range: 0 to 5). The mean for the return to baseline was 4 (range: 0 to 7.5). On the final day, the mean for the two contingent music sessions was 3. The baseline mean for mouth opening was .34 (range: 0 to 3). The contingent music phase mean was .50 (range: 0 to 1.5).

Two of the three behaviors were raised by contingent music to a moderate though variable degree. The effect of contingent music on the first two behaviors appears to be questionable in the latter sessions. The third behavior was not affected.

For Patient 3 (Figure 3) the mean for the baseline phase for lateral head movement was .17 (range: 0 to 1). During the contingent music phase the mean was 1.1 (range: 0 to 5). The mean for the first baseline for eye focus was .44 (range: 0 to 1.5). During the first contingent music phase the mean was 2 (range: 0 to 6). The mean for baseline 2 was .25 (range: 0 to 1) and the mean for the final day in which contingent music was reinstated was 0. The baseline mean for mouth opening was 0 (range: 0 to .5) and the mean for the contingent music phase was .31 (range: 0 to 3). It should be noted that the patient suffered labile hypertensive crises beginning on day 26 and continuing throughout the remainder of the study.

The effects of contingent music were slight but apparent for two of the three behaviors. The development of severe blood pressure difficulties after session 48 probably affected the

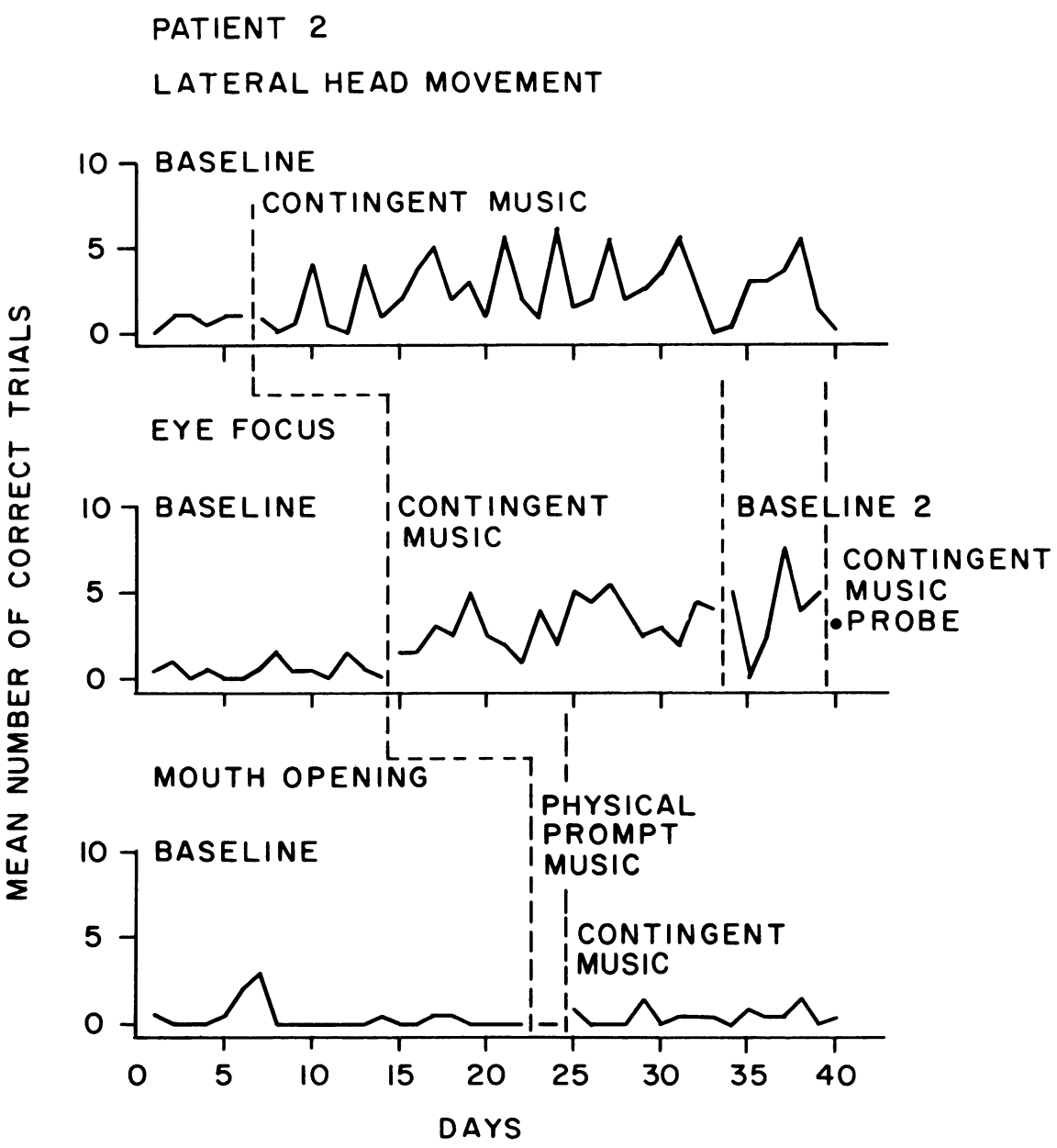

Fig. 2. Daily means of correct trials by Patient 2 for lateral head movement, eye focus, and mouth opening.

continuing test of contingent music on the first two behaviors. The third behavior showed questionable, if any, effects of contingent music.

DISCUSSION

These data indicate that selected responses to environmental stimuli of one patient in a vegetative state were brought under environmental control. Lesser control was evident for the second patient who had been in a persistent vegetative state for 38 mo. Because of the third patient's labile hypertension, it is difficult to draw any conclusions regarding the data. Results show that adaptation of the experimental analysis procedures used should be a useful and even

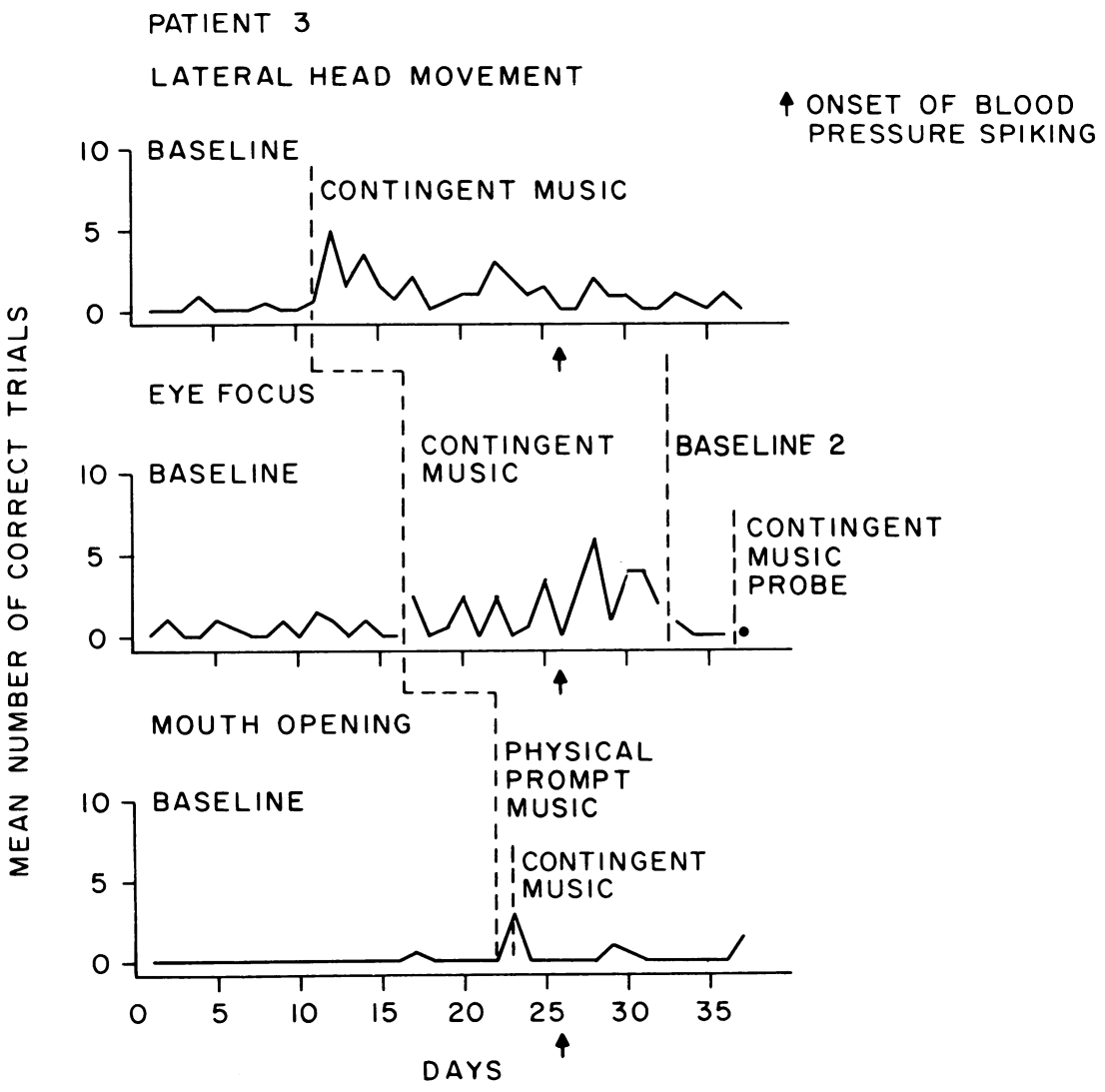

Fig. 3. Daily means of correct trials by Patient 3 for lateral head movement, eye focus, and mouth opening.

necessary step to take with some comatose patients.

The choice of an overt response as an assessment measure was dictated by the characteristics of the vegetative state. "The common denominator is the appearance of wakefulness without any external evidence of communication or complex behavior" (Levy, Knill-Jones, & Plum, 1978, p. 301). The task of following directions was chosen because it directly related to a criterion essential to diagnosis of the condition. "Behaviorally, one can estimate another person's self-aware consciousness only by his response to the examiner's verbal commands or gestures" (Plum & Posner, 1980, p. 23).

The vegetative state is homogeneous only with regard to behavior. The patients in this study were further categorized as vegetative or persistent vegetative. The latter term denotes a much more severe condition. Plum notes that the vegetative state may be transient (Posner, 1978), and that the facilitation of this transience would be related to the development of consistent movements. In the vegetative state, the stillness of many patients is striking, as was evident in the three patients examined in the

study. Increased variability in responding may be a sign of progress, because the alternation between activity and stillness stands in contrast to the operational definition of the state as "chronically unresponsive" (Plum & Posner, 1980, p. 3).

Contingent music had strong effects on both the number of correct trials and the topography of the movements in Patient 1. However, the experimenters had hoped that the patient could be trained to awaken to the experimenter's voice. This did not occur. Therefore, the variability seen in data for Patient 1 probably includes a sleep factor. Patients 2 and 3 were shaken until their eyes opened spontaneously after five trials in which their eyes were closed. The session was cancelled if either the experimenter or a nurse could not shake the patients awake.

Changes in the topography of movement was most noticeable with finger movement trials (Patient 1). The observers were observing both hands throughout, although they were told initially that they should observe only the patient's right hand, as the other was considered incapable of movement. During treatment conditions for the finger movements, the experimenter and observer noted twitches in the left hand for five consecutive trials. These were reinforced. The movements of this hand over the treatment phase changed so radically that the patient became a management problem due to using his left hand to pull out his gastronomy tube.

The effects of contingent music were not as strong for Patient 2, but the mere occurrence of responses for a patient who was in a persistent vegetative state is surprising. During treatment, the number of correct trials increased, but there was no change in topography. However, during Baseline 2, the patient focused on the experimenter for up to the full 10-sec interval on several occasions.

The effects for Patient 3 were slight, questionable, and complicated by the development of labile hypertension. Patient 3 died within 1 wk of the conclusion of the experiment.

The patient in the least deteriorated state, Patient 1, showed the strongest effect. This suggests that the operant assessment and treatment of comatose patients would hold the greatest promise for those patients who have more recently become comatose and who have less severe or extensive head injuries. Patient 1 did eventually recover from the vegetative state, but with severe impairments. Patient 2 did not recover.

Future research will need to concentrate on the variability that occurred during the treatment phases. To reduce this variability, this procedure needs to be modified in at least two ways. A screening procedure is necessary to ascertain alert and nonalert stages. The Glasgow Coma Scale (Habbema et al., 1979; Teasdale et al., 1979) records only the best response occurring in a given time period; other responses are omitted. In contrast, the operant procedure records and retains all responses. Second, the length of the session needs to be adjusted according to the information derived from this screening procedure. A changing criterion design might be used.

The most important contribution of this experiment is the finding that experimental analysis procedures may expand the assessment of the comatose patient. The contingent music proved useful, although other consequences such as audio or videotaped statements of family members might be used. Operant procedures may be a useful treatment with some patients, provided assessment and treatment is begun at the onset of the vegetative state. Future research needs to determine whether the procedures can be useful with acute coma patients. The leading medical researchers have emphasized the importance of overt behaviors (Bates et al., 1977; Jennett & Plum, 1972; Levy et al., 1981), yet they have not used operant as well as respondent procedures to assess total response possibilities.

The idiosyncratic nature of the covert responses of these patients emphasizes the importance of reliable assessment of overt responses. In the rush to use new instruments for

measuring covert responses, it is easy to allow the overt response to become of secondary importance. Skinner's (1974) reminder that the skin offers no special boundary should also be interpreted to emphasize the equal importance of the overt response.

The data raise many interesting issues, e.g., (a) for Patients 2 and 3, mouth opening responses did not respond to treatment; (b) the variability was extensive during treatment phases, yet the occurrence of variability was in itself an effect; and (c) the relationship between covert behaviors and overt behaviors is unknown. The scientific practice of the experimental analysis of behavior does, however, provide new tools to study these questions. The data show that a more expanded analysis of operant behavior is warranted with patients in vegetative states following acute coma. Additionally, patients with related response deficits, such as those suffered by stroke victims, might also benefit from operant analysis and treatment.

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