INSTRUMENTATION & TECHNIQUES

A variable-temperature surrogate mother for studying attachment in infant monkeys*

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A variable-temperature surrogate mother for use with infant monkeys is described. The apparatus is designed to facilitate manipulation of the infant-surrogate attachment bond. Data showing significant behavioral changes in ventral contact and locomotion as a function of depressed surrogate temperature are presented. The value of this technique in the production of psychopathology is indicated by a dramatic and progressive increase in disturbance behaviors during a 9-week test period. Implications for the use of a variable-temperature surrogate in studying animal models of psychopathology are noted.

The traumatic effects of separation from an attachment object, either maternal or cagemate, have been demonstrated in many studies (McKinney, Suomi, & Harlow, 1973). The effects of maternal rejection of the infant have been harder to demonstrate because of the obvious methodological difficulties in controlling abusive behaviors of real monkey mothers (Harlow, Harlow, Dodsworth, & Arling, 1966), as well as technical problems in constructing and maintaining an artificial or surrogate mother capable of effectively rejecting the infant (Rosenblum & Harlow, 1963; Furchner & Harlow, 1969; Harlow, Harlow, & Suomi, 1971).

Harlow and Suomi (1970) tested the technique of lowering surrogate body temperature as a means of manipulating the attachment of infant monkeys to their surrogates. They found that a chilled surrogate markedly reduced the amount of contact the infant made with its foster mother. More efficient manipulation of temperature variables awaited the development of new apparatus capable of both rapid heating and cooling. The present apparatus is designed to fulfill these requirements by enabling the E to heat or cool rapidly, accurately, and reliably each of four surrogates independently.

METHOD

Apparatus

The apparatus consists of two major parts: a stainless steel quad cage 36 x 24 x 24 in. described previously (Suomi & Harlow, 1969) and four surrogates, one housed in each quadrant of the cage. The quad cage is divided by Masonite panels into four 24 x 18 x 24 in. quadrants. Thus, four infant monkeys may

be housed individually, each living in a quadrant of the cage with its own surrogate as illustrated in Fig. 1.

Each surrogate has a spine of copper pipe as a foundation and a coil of copper ribs surrounding the spine to form a body as illustrated in Fig. 2. The surrogate body can be cooled by a system of recirculating Freon 12 or heated by a pair of small electric heating pads. The spine is made from a 12-in. and a 30-in. length of 1½-in.-diam copper pipe. The 12-in. portion of pipe is silver soldered to the 30-in. portion at a 135-deg angle. When finished, the surrogate is suspended from the roof of the cage by the 30-in. portion of pipe and the 12-in. section forms a 35-deg angle with the cage floor, enabling the infant monkey to cling comfortably to the finished surrogate. The body of each surrogate is formed by coiling a partially flattened 15-ft length of 5/8-in. copper tubing into a cylindrical shape about 5 in. in diam and 12 in. long. The lower portion of the spine is then positioned within the coiled copper tubing body of the surrogate and soldered in place. Two lengths of 3/8-in.-diam copper tubing used for carrying Freon to and from the surrogate body are contained within the spine. These tubes connect at their lower ends to the open ends of the partially flattened coil of copper tubing which comprises the surrogate body. One of these tubes acts as a feeder line for the saturated Freon 12 vapor. The other tube returns the expanded vapor after use in cooling the coil to a ½-hp compressor located outside the room housing the quad cage.

Figure 3 is a schematic diagram illustrating the complete refrigeration system. Liquid Freon is pumped by the compressor through a 3/8-in. copper tube to a Sporlan expansion valve

Fig. 1. Quad cage housing four infant monkeys separately with their surrogates.

*This research was supported by USPHS Grants MH-11894 and MH-18070 from the National Institute of Mental Health to the University of Wisconsin Primate Laboratory and by the Grant Foundation.

Fig. 2. The variable-temperature surrogate body.

SCHEMATIC DIAGRAM OF
SURROGATE COOLING SYSTEM

Fig. 3. Schematic view of refrigeration apparatus for cooling surrogates.

(Type GF1C, Sporlan Valve Co., St. Louis, Missouri) located above the quad cage. From the expansion valve, saturated vapor is fed to a manifold with four exits, one for each surrogate. Flow of the refrigerant to each surrogate is independently controlled by a Sporlan solenoid valve located between the manifold and the copper spine supporting the body. After traveling down the spine and cooling the surrogate's body, the Freon returns back up the spine into a return manifold and then is drawn through a 1/2-in.-diam copper vacuum line back to the compressor. This completes the refrigeration circuit.

Heat for each surrogate is provided by two Watlow (Watlow Electric Manufacturing Co., St. Louis, Missouri) 250-W 5 x 10 x

1/16 in. heater pads. These are designed to prevent ice from forming on the surface of airplane wings, and are more than sufficient to bring a chilled surrogate back to body temperature in approximately 4 min. These pads are held firmly against the interior of the copper coil by a sheath of stainless steel inside the surrogate body. Power is brought to the heating pads through a flexible shielded conduit running up the spine to a Watlow thermostatic control (Type RO-1) providing independent temperature regulation for each surrogate. A capillary tube from the thermostat runs down the spine to a heat-sensing bulb located between the copper coils of the body and one of the heating pads as illustrated in Fig. 2.

The head of each surrogate is constructed of stainless steel. Within each head is a small lamp (No. 46, 6.3 V, 0.25 A) and a speaker (Speco, Model U-240, 8 ohms, 2 in. in diam) giving the surrogate the potential of producing two separate cues to signal acceptance or rejection. Electrical current for these cues is supplied by plugging the short power cable from the head into an outlet on the spine: the outlet is wired to a control panel in an adjacent room. The body of each surrogate is covered by a cylindrical terrycloth sheath designed to fit tightly over the cooling coils. Draw strings at the open end of the bag-like sheath are used to pull the cloth tight around the spinal pipe beneath the head.

The surface temperature of each of the four terrycloth-covered surrogates was recorded during cooling and heating periods. Heating and cooling characteristics were found to be very similar between surrogates. The mean time required to heat or cool a surrogate between 37° and 5°C is 4 min. Thermostatic control of the heating pads allows one to set the desired heating temperature between 60° and 250°F, and this temperature will be maintained as long as current is supplied. Cooling temperature is controlled at the compressor by adjusting the pressure difference on either side of the expansion valve. Increasing the pressure difference decreases the temperature at the surrogate. Every cooling system is unique, and we have found a high side or liquid side pressure of 130 lb/sq in. and a low side or vacuum side pressure of 30 lb/sq in. to give the desired resulting temperature of slightly above freezing.

Maintenance of monkey apparatus is always a primary consideration of the E. Monkeys display great ingenuity and appear to take great pleasure in dismantling and destroying everything in their environment. No apparatus may be described as monkeyproof, but our surrogates have resisted destruction, and we feel safe in predicting a surrogate lifespan of at least several years. Cage cleaning as well as surrogate cleaning present no obstacle. Removal of the monkeys, surrogate heads, and terrycloth covers is all that is necessary for washing the apparatus.

SUPPORTING DATA

Four rhesus monkeys, two males and two females, were individually housed in wire cages in the lab nursery for the first 3 months of life. During this time, they became attached to a terrycloth-covered wooden simplified surrogate as described by Harlow and Suomi (1970). We thought that infant attachment would transfer readily to the copper-coil foster mothers which were roughly similar outwardly if not inwardly. This proved to be the case: when the infants were transferred to individual quadrants of the cage, each jumped onto its warm foster mother and clung to her with an attachment as great or perhaps greater than that shown to her wooden counterpart. For the next 4 weeks, the Ss were given an opportunity to adapt to their new surroundings and consolidate their attachment to the copper-coil surrogates. During this period, the temperature of the surrogates was maintained at a constant 100°F, approximating normal monkey body temperature when the insulation of the cloth cover is taken into account.

From the beginning of the 5th week to the end of the 13th week, each infant was behavior-scored three times a day for 5 days each week by a thoroughly trained observer. The daily test sessions were at 9:00 a.m., 1:00 p.m., and 7:00 p.m. The order of observation of each infant was chosen randomly before each testing session. Between testing sessions, the temperature of

Fig. 4. Effect of cold periods on the frequency of ventral contact with the surrogate.

each surrogate mother was maintained at 100°F. Each testing session was divided into three phases, an initial warm period, a cold period, and finally a rewarm period. The initial phase of each testing session began with a 5-min behavior-scoring period for each infant. The second phase of the test session consisted of cooling the surrogate by throwing the remote switch for each solenoid valve to the open position and at the same time turning off the power for the heating pads. Having done this, the observer then waited 5 min for the surrogates to cool and then proceeded with a second 5-min behavioral-scoring period for each infant. The third phase began by closing the solenoid valves and turning on the heating pads. The observer again waited 5 min, this time for the surrogates to warm up. A final 5-min behavioral-scoring period for each infant ended the testing sessions. The data obtained from this schedule made it possible to compare infant reactions before, during, and after the chilling period as well as behavioral changes developing over the 9 weeks of this study.

Two of the most striking results of this study are shown graphically in Figs. 4 and 5. Ventral contact, time spent clinging to the surrogate, shows a sharp decrease during the cold period ($p < .005$) as illustrated in Fig. 4. This points up the efficiency and long-term consistency of the temperature variable over previous attempts to build a rejecting surrogate using a variety of techniques ranging from sandpaper covers to hidden spikes (Harlow, Harlow, & Suomi, 1971). The significance of temperature change as a technique of forcing an infant to leave his surrogate was first suggested by Harlow and

Fig. 5. Increase in disturbance behaviors produced over the 9-week study period.

Suomi (1970) using cold running water as coolant. The present findings supplement their preliminary observations of infant monkey responses to a cold-running surrogate.

Locomotion was found to increase significantly

during the cold periods ($p < .05$), perhaps reflecting the disturbance of the infant at finding this cold shoulder and his agitation at being continuously rebuffed. However, the most promising finding from the viewpoint of experimental psychopathology was a sharp and dramatic increase over the 9-week study period in disturbance as measured by rocking, huddling, and self-clasping. This disturbance increase appeared in all four animals and grew much more pronounced during the later weeks of the study period ($p < .025$), as illustrated in Fig. 5. The typical response of an infant to his cold surrogate was rocking and huddling in the corner opposite the surrogate. Research is currently in progress to evaluate the significance of this finding.

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(Received for publication January 24, 1973;
revision received February 14, 1973.)