has only limited control over successive ISI in a given list. For instance, if the ISI between Items 1 and 2 is fixed, then the ISI between Items 2 and 3 must be some multiple of this value. This results from the fact that the only way to vary ISI for a fixed speed is to vary the spacing between items.

As indicated previously, the shortest feasible ISI with the present apparatus is 25 msec. The photocell system is unable to follow at shorter intervals due to unavoidable scattering of light as it passes through the hole in the sliding plate. To shorten the interval, it would be necessary to change the gear ratios as well as to

modify the photocell system. It would appear feasible to have two parallel columns of holes on the sliding plate, the holes in one column aligned with the odd-numbered stimulus lines and the holes of the other aligned with the even-numbered lines. Then, if each column had its own independent light source, photocell, and light-impulse detector, the two outputs could be fed in common to the strob unit. Theoretically, the wider spacing of the holes in a given column should handle the problem of light scatter while permitting the present minimum ISI to be halved.

The costs of the major components were

as follows: motor and control unit, \$130; stroboslave, \$195; and light-impulse detector, \$60.

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NOTE

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The use of hypothermia in split-brain surgery on the rat¹

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A method of simple split-brain surgery on the rat is described. Rats were anesthetized, subjected to hypothermia, and split-brain surgery was performed. With precautions to avoid overdose of anesthetic, limit the minimal temperature to 22°C, and regulate the rate of rewarming, animals survived and on the day following surgery showed no adverse effects. No extensive tissue degeneration was found.

In the past decade much interest has been aroused by research involving split-brain preparations. Generally, publications based on this method of animal research have come from laboratories with facilities large enough to house and maintain larger animals (e.g., cats and primates). These laboratories have also been equipped for antiseptic surgery, the surgical procedure involving careful aspiration of neural tissue connecting the two brain halves (Sperry, 1968). In an animal smaller than a cat, the small size of the decussation and the limited skull area available for access makes this surgery very difficult.

In an effort to devise a more practical surgical method for use with the laboratory rat, the use of hypothermia was explored. By reducing body temperature and using an anesthetic to prevent thermogenesis by shivering (Boba, 1960), it is possible to reduce heart rate, cardiac output, arterial pressure, and oxygen consumption, and increase blood viscosity (Bigelow, 1950; Bullard, 1959).

The brain also shows a general reduction

of metabolic rate during hypothermia, which is completely reversible upon rewarming (Fazekas & Himwich, 1939; Lougheed, Sweet, White, & Brewster, 1955; Rosomoff & Holaday, 1954).

In humans, all measurable nervous activity disappears below 25°C to 20°C (Henderson, 1966). In other homeotherms, the temperature at which activity ceases varies. The rat, at 22°C, shows activity greatly reduced from that recorded at 36°C, according to electrocorticograms made locally.

Of special importance in neurosurgery is the fact that brain volume, intracranial pressure, cerebrospinal fluid pressure, and venous pressure are also reduced (Rosomoff & Gilbert, 1955). In comparing an experimentally produced injury during hypothermia with one produced during normothermia, it has been shown that the area of inflammatory reaction is more localized under hypothermia and that the progress from the exudative stage to the reparative stage is more rapid (Rosomoff, 1959). In the Rosomoff study, hypothermia was discontinued 1 h after injury. Continued hypothermia was unnecessary to obtain the desired effects (Rosomoff, 1959).

While body temperature in dogs has been reduced experimentally to 1.5°C with complete recovery (Gollan, Tysinger, Grace, Kory, & Meneely, 1955), in practice, a minimum temperature of 22°C should be observed in surgery with the rat. Fatal ventricular fibrillations occur in most homeotherms between 20°C and 22°C (Nielsen, Owman, & Rosengren, 1968; Bennett, Smookler, & Buckley, 1968). These fibrillations appear to be the result of sympathetic nervous-system activity.

Normal rhythmic activity has been maintained below 20°C by using an adrenergic blocking agent (Nielsen et al, 1968) or by reducing epinephrine output to practically zero by drug effect (Bennett et al, 1968).

Respiratory failure is also a problem at 22°C (Boba, 1960). It has been suggested that this may be the result of an overdose of the anesthetic. With the reduced metabolism, less and less anesthetic is required as the body temperature drops and an overdose easily occurs (Boba, 1960).

METHOD

Rats of approximately 300 g were anesthetized with a 3% solution of chloral hydrate, using 1 cc for each 100 g of body weight. An incision was made through the skin, and the skull was scraped clean. Four small holes were drilled through the skull as far laterally from the central sagittal suture as possible. These holes assist in the release of any pressure build-up during or after rewarming.

Rectal temperature was monitored. Temperatures ranged from 34.5°C to 36°C.

Cooling was initiated by laying the animal on a plastic bag filled with crushed ice and placing another bag of ice on its back and neck. Body temperature fell at a rate of approximately 3°C in 5 min, depending on the body area in contact with the ice bags and the surface-to-mass ratio.

Caution was exercised to prevent the reduction of the temperature below the minimum desired. As the method is one of indirect bloodstream cooling, the area in contact with the ice bags will be cooler than the core temperature measured by the

rectal thermometer; it will continue to cool the blood for some minutes after the removal of the ice. At a core temperature of 26°C, the ice was removed. If the rectal temperature did not reach the desired level, ice was reapplied for brief periods of time.

The animal was placed on a stereotaxic apparatus with a scalpel blade fixed to the carrier. Three-dimensional coordinates, with the scalpel tip at bregma, were recorded. After moving the carrier to one side, a dentist's diamond wheel was used to grind away the skull until a narrow channel through the skull was obtained along the length of the sagittal suture above the area to be sectioned. The deGroot atlas was used to establish the limits of the section. The scalpel blade was positioned vertically 4 mm anterior to bregma and lowered to a depth of 11 mm from the surface of the skull at bregma. The most anterior structures were severed and the blade was moved horizontally to 5 mm posterior to bregma to sever the posterior structures. Bleeding occurred at this point as the scalpel passed along the length of the superior sagittal sinus.

After removing the scalpel blade, the area was washed with Ringers solution until blood ceased to issue from the channel. The channel and the small holes drilled laterally were left open to allow any seepage to escape. Wound clips closed the incision, and the animal was removed from the stereotaxic apparatus.

Others have shown that in rewarming, blood volume increases above normal as the cells give up fluids (Block, 1969). Rapid rewarming would tend to intensify this problem. Also, with external warming, demands are placed on the circulatory and respiratory systems that have not rewarmed sufficiently to meet these demands (Henderson, 1966).

Using chloral hydrate or barbiturates, the animal remains deeply anesthetized for several hours. As shivering is prevented, it is desirable to allow the return to normal temperature without external warming. If

spontaneous rewarming increased the temperature by 1°C in 10-15 min, no external warming was used. If the temperature did not increase or the animal warmed very slowly spontaneously, he was placed under an incandescent lamp until the core temperature began to rise. Animals that regained 5°C within the first hour after the core temperature reached a minimum survived.

At 26°C to 27°C, rewarming rate was greatly reduced and one of our animals required 7 h to return to 36°C from a low of 22.4°C during surgery.

RESULTS

On the day following surgery, animals appeared normal, healthy, and vigorous. A fiber degeneration study on one of the Ss showed scattered degeneration throughout the cortex, as might be expected with the sectioning of the major decussating tracts to cortical areas. No areas of extensive degeneration were observed.

DISCUSSION²

The use of total or partial split-brain preparations in research will be greatly facilitated if the laboratory rat can be used as an S. The use of hypothermia appears to overcome the major problems in split-brain surgery with small animals.

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NOTES

1. Appreciation is expressed to Dr. Francis P. Leukel for his assistance in the development of this method and in the preparation of the manuscript.
2. This method was developed using albino rats. However, hooded rats have substantially more uncrossed optic fibers (Lund, 1965) and should be considered in experiments requiring complete section through the optic chiasma.