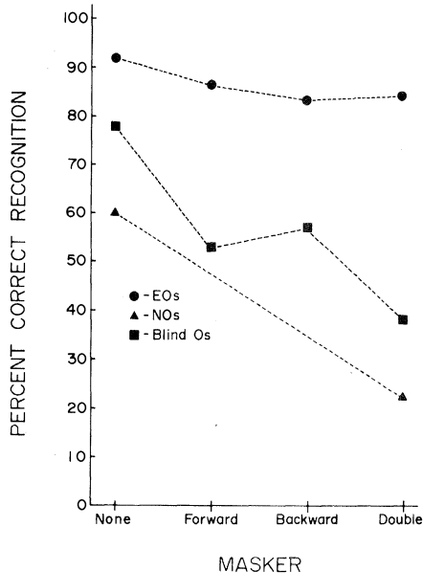
Fig. 2. Mean percentage correct letter recognition as a function of the nature of the masking stimulus.

previous experience on the kinotact, were performing with nearly 100 percent accuracy at the end of 15 trials (*12*).

One indication that the ability of the EO's to read is not the result of some superior general cognitive ability comes from some visual pattern-recognition measurements. In one experiment, both EO's and NO's viewed the visual monitor of the Optacon. The monitor, which consists of a 6 by 24 array of light-emitting diodes, shows which pins on the tactile array are turned on. As the camera of the Optacon is moved across printed material, the same material passes across the screen of the monitor, producing an effect similar to that of the Times Square news display. The limited field of view, one letter, prevents rapid reading. As the camera was passed slowly across the printed material, both EO's and NO's could read the material visually. As the camera was moved more rapidly and display times became shorter than approximately 120 msec, both EO's and NO's began to make errors in reading, a result in agreement with a similar experiment performed by Taenzer (*13*). Neither of the two EO's performed better than the three NO's tested. At display times shorter than 90 msec, the accuracy of the NO's had dropped to 92 percent, whereas J.L.'s score was 82 percent. The accuracy of V.B. dropped to less than 18 percent. For those accustomed to categorizing the skin as one of the "minor senses," there is the unusual phenomenon of V.B.'s being presented identical information through two different displays—one visual, one tactile—and being able to read the tactile display at rates higher than those at which she could read the visual display.

A number of other measurements of basic tactile sensitivity have not revealed differences that would seem to account for the tactile pattern perception performance of the EO's. Measurements of vibrotactile thresholds on the fingertip showed one EO to be somewhat more sensitive than the NO's tested and the other EO to be slightly less sensitive. Both EO's showed masking as measured by changes in detectability of vibrotactile signals, although in amounts somewhat less than the NO's showed. Both EO's showed spatial summation on the skin and attenuation of spatial summation in the presence of masking stimuli similar to those of NO's (*14*). Measurements of temporal order for tactile stimuli (*15*) showed one EO to have a relatively small threshold for temporal order and one to have a relatively large threshold. Whatever the ability or abilities of these EO's that may underlie their extraordinary tactile performances, they are not revealed by these kinds of psychophysical measurements. Moreover, we do not yet know whether the measurement of such abilities would prove useful in screening potential users of the Optacon or whether, in fact, such abilities can be trained.

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7. With reading material consisting of both uppercase and lowercase letters of the alphabet, a display time of 90 msec corresponds to a rate of approximately 92 words per minute; a display time of 170 msec, 46 words per minute; and a display time of 670 msec, 11 words per minute.
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# Monosodium Glutamate Administration to the Newborn Reduces Reproductive Ability in Female and Male Mice

Abstract. *Monosodium glutamate (MSG) administered during the neonatal period (days 2 to 11) resulted in a sequence of events that were manifested in adulthood. Reproductive dysfunction was seen in both female and male animals. Females treated with MSG had fewer pregnancies and smaller litters, while males treated with MSG showed reduced fertility. The MSG-treated mice showed increased body weight and decreased pituitary, thyroid, ovary, or testis weights.*

Monosodium glutamate (MSG) produces lesions in the brains of various mammals (*1–3*). This damage occurs primarily in structures contiguous with ventricular cerebral spinal fluid and is best demonstrated in the arcuate nucleus of the hypothalamus. Concomitant with this damage to the central nervous system (CNS), there are reports of a number of somatic and behavioral dysfunctions including stunted skeletal growth, obesity, abnormal activity levels, sterility in female mice, and learning deficits (*1, 4–6*). While several investigators have reported impaired reproductive capacity in MSG-treated mice (*1, 3, 7*), there are no systematic and quantitative reports of reproductive dysfunction after administration of MSG to the newborn. In contrast, several studies have reported failure to find reproductive deficits in rats treated with MSG during the neonatal period (*8, 9*).

We present evidence of reduced fertility in both male and female mice treated with MSG during the first 10 days after birth. Animals treated with MSG also show reduced endocrine gland weights at autopsy. These results along with our finding of delayed vaginal canalization

and differences in the length of various stages of the estrous cycle indicate an impairment of the hypothalamic-hypophyseal regulation of reproduction.

We used BLU:Ha(ICR) mice (Blue Spruce Farms, Altamont, N.Y.); they were housed in plastic cages, given free access to food and water, and maintained on a 12-hour light-dark schedule. All the newborn animals were kept with their dams until 29 days of age. The MSG was administered to all treated animals from days 2 to 11 of life, and followed the original schedule of Potts *et al.* (*10*), which was also used by Olney (*1*) and Trentini *et al.* (*9*). Essentially, this schedule calls for the subcutaneous administration of a gradually increasing dose of MSG from 2.2 to 4.2 mg per gram of body weight. Littermate control animals received equal volumes of bacteriostatic water. In the first reproduction study, there were five mating environments, each composed of two MSG-treated female mice, two control females, and one normal male; the females were exposed to the male for 60 days starting at 200 days of age. Male animals were killed between 295 and 302 days of age; at autopsy the pituitary, thyroid, testes, and adrenal glands were removed and weighed. In the matings of MSG-treated and control females with a normal male, the major findings are seen in the number of pregnancies and litter size, which are significantly reduced in MSG-treated females (Table 1). The results of the endocrine autopsies for the males are shown in Table 2. These measures are given in absolute weights since the MSG-treated mice are significantly heavier than controls, a finding which replicates that of others reporting MSG-induced obesity (*1, 5, 6*). The obvious reduction in weight of those endocrine glands necessary for reproductive function in the male led us to carry out a second study designed to test for reproductive dysfunction in both female and male mice treated with MSG.

The second study was carried out exactly as the first, except that animals were mated at 100 days of age and the mating period was restricted to 30 days. The MSG-treated male animals being tested were housed with one control female for the same period. Vaginal smears were taken daily for 21 days immediately before mating occurred. Autopsies were done at 171 and 191 days of age for the male and female mice, respectively (Table 1). The results of the first study on female reproduction were replicated, with a decreased number of pregnancies and reduced litter size seen in the MSG-treated females. A small but highly significant reduction of birth weights also occurred. An autopsy of the female endocrine glands shows the same pattern as that of the males with pituitaries, thyroids, and ovaries showing reduced weights (Table 2). Several added indicators of endocrine dysfunction were observed. The MSG-treated females showed a significant delay in vaginal canalization (43 days for the MSG-treated animals compared to 37 days for controls; $P < .01$, *t*-test, two-tailed). The MSG-treated females also had longer estrous cycles than the controls (10.0 and 7.26 days, respectively; $P < .05$) and a higher incidence of metestrus (7.33 and 4.10 days of the entire 21-day test period, respectively; $P < .02$), but a lower incidence of proestrus (0.44 and 2.00 days, respectively; $P < .01$). Further, all seven of the MSG-treated mice that failed to become pregnant remained exclusively in diestrus and metestrus for 30 days after the termination of the mating period, when testing was discontinued. We also found that MSG-treated males failed to impregnate control females as readily as did control males (Table 1). The MSG-treated males showed a number of signs that led us to suspect reduced fertility, for example, reduced testicular weight, undescended testes, and reduced pituitary weight (Table 2). When MSG-treated males were successful in impreg-

Table 1. Monosodium glutamate and reproduction. Results are means ± the standard error of the mean.

| Number of pregnancies | | Litter size (mean No.) | | Mean birth weight (g) | | Mean weight at 30 days (g) | |
|---|---|---|---|---|---|---|---|
| Controls | MSG | Controls | MSG | Controls | MSG | Controls | MSG |
| *MSG-treated and control females mated with control males: reproduction 1* | | | | | | | |
| 9/10 | 3/10 | 10.66 (±0.38) $N = 9$ | 4.00 (±0.28) $N = 3$ | 1.55 (±0.01) $N = 96$ | 1.46 (±0.04) $N = 12$ | 19.11 (±0.33) $N = 90$ | 21.99 (±0.97) $N = 7$ |
| $P < .009$* (Fisher's) | | $P < .02$† (Mann-Whitney) | | NS (*t*-test) | | $P < .05$† (*t*-test) | |
| *MSG-treated and control females mated with control males: reproduction 2* | | | | | | | |
| 12/12 | 5/12 | 10.08 (±0.52) $N = 12$ | 4.80 (±0.73) $N = 5$ | 1.59 (±0.01) $N = 121$ | 1.39 (±0.03) $N = 24$ | 17.51 (±0.26) $N = 116$ | 20.95 (±0.50) $N = 23$ |
| $P < .0002$* (Fisher's) | | $P < .0005$* (Mann-Whitney) | | $P < .0001$† (*t*-test) | | $P < .0001$† (*t*-test) | |
| *MSG-treated and control males mated with control females: reproduction 2* | | | | | | | |
| 12/12 | 6/11 | 10.08 (±0.52) $N = 12$ | 12.16 (±0.77) $N = 6$ | 1.59 (±0.01) $N = 121$ | 1.60 (±0.01) $N = 73$ | 17.51 (±0.26) $N = 116$ | 17.47 (±0.35) $N = 64$ |
| $P < .01$* (Fisher's) | | NS (Mann-Whitney) | | NS (*t*-test) | | NS (*t*-test) | |

*$P$ values are one-tailed. †$P$ values are two-tailed.

Table 2. Mean autopsy weights of endocrine glands.

| | Control ± S.E.M. | MSG-treated ± S.E.M. | $P$ |
|---|---|---|---|
| *MSG-treated and control males: reproduction 1* | | | |
| Body weight (g) | 37.20 ± 1.04 | 46.26 ± 2.25 | <.0005* |
| Pituitary (mg) | 2.42 ± 0.24 | 1.57 ± 0.10 | <.01† |
| Thyroid (mg) | 4.22 ± 0.36 | 2.99 ± 0.29 | <.02† |
| Testes (mg) | 232.73 ± 11.41 | 185.61 ± 11.35 | <.01† |
| Adrenals (mg) | 5.51 ± 0.40 | 5.66 ± 0.35 | NS |
| *MSG-treated and control males: reproduction 2* | | | |
| Body weight (g) | 39.46 ± 1.83 | 44.81 ± 1.59 | <.005* |
| Pituitary (mg) | 2.63 ± 0.19 | 1.15 ± 0.17 | <.0005* |
| Thyroid (mg) | 4.36 ± 0.33 | 3.24 ± 0.28 | <.005* |
| Testes (mg) | 286.44 ± 11.97 | 198.30 ± 9.45 | <.0005* |
| Adrenals (mg) | 5.45 ± 0.28 | 5.73 ± 0.59 | NS |
| *MSG-treated and control females: reproduction 2* | | | |
| Body weight (g) | 33.21 ± 1.44 | 42.44 ± 1.27 | <.0005* |
| Pituitary (mg) | 2.90 ± 0.41 | 1.27 ± 0.09 | <.001† |
| Thyroid (mg) | 4.15 ± 0.18 | 3.40 ± 0.16 | <.01† |
| Ovaries (mg) | 29.35 ± 1.44 | 21.86 ± 3.19 | <.05† |
| Adrenals (mg) | 10.58 ± 0.50 | 8.35 ± 0.61 | <.01† |

*$P$ values are one-tailed (Student's *t*-test). †$P$ values are two-tailed (Student's *t*-test).

nating control female mice there were no untoward effects as judged by litter size, nearly identical birth weights, and weights of offspring at 30 days of age (Table 1). Offspring of MSG-treated females were significantly heavier at 30 days of age (Table 1). This was most likely the result of the reduced litter size seen in the MSG-treated females, which in turn allowed for increased availability of mother's milk. These weight differences were not observed in the male reproduction series (Table 1) when litter size is comparable.

The occurrence of reproductive dysfunction in both the female and male mouse along with reduced endocrine gland weights leads us to suspect that MSG administered during the neonatal period results in hypothalamic damage leading to multiple endocrine dysfunction. The multiple endocrine dysfunction hypothesis would account for a number of the behavioral observations made by us and other investigators. Stunted skeletal growth and obesity may result from disturbance of growth hormone (GH) production and release. Our obese animals consistently show abnormally large deposits of fatty tissue in the peritoneal cavity on autopsy. The role of GH in the mobilization of nonesterified fatty acids from fat deposits may, in part, account for the obesity of MSG-treated mice. The consistently reduced thyroid weights recorded above indicate a reduced secretion of thyroid-stimulating hormone which again suggests hypothalamic damage. Thyroid dysfunction may also account for the reduced activity that we observed and the decreased oxygen consumption reported by Djazayery *et al.* (*11*), indicating a much reduced metabolic rate. Early thyroid dysfunction may also affect CNS growth and development resulting in learning deficits. Finally, damage to the hypothalamus can result in decreased secretions of gonadotrophins necessary for female and male reproduction.

The delayed puberty seen in this study, indicated by delayed vaginal openings, is probably the result of a decreased estrogen output, since vaginal opening occurs as the result of an initial release of large amounts of ovarian estrogen. This suggests a delay in the initial release of gonadotrophin necessary for ovarian stimulation. The longer estrous cycles, decreased incidence of proestrus, and decreased ovarian weights indicate that gonadotrophin release is also impaired after puberty. These conclusions are supported by others who have noted irregularities in the estrous cycle and reduction in pituitary prolactin and mammary gland development (*3*), along with a decrease in pituitary luteinizing hormone (*12*). A study on golden hamsters, in which the doses of MSG were higher than those we used, showed females to be acyclic with small follicles and no corpora lutea, while males had atrophic seminiferous tubules and reduced spermatogenesis (*13*). Thus, the reduced female fertility observed here may be due to either a decreased incidence of ovulation or a failure of implantation—events which are dependent on luteinizing hormone and prolactin. The decreased number of pregnancies from matings of control females and MSG-treated males is probably due to decreased spermatogenesis.

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## Chromatic Organization of Primate Cones

Abstract. *The distributions of baboon retinal cones were mapped histochemically by light-stimulated reduction of nitroblue tetrazolium chloride. Blue cones were distributed regularly in the periphery; red and green cones were distributed randomly everywhere. The ordering of cone densities was green > red > blue.*

Delineating the retinal circuits that channel and process chromatic information requires knowing the spectral classes of cone photoreceptors and how they are organized into a two-dimensional sensor matrix. The spectral types of goldfish cones have been classified by their morphologies and mosaic organization (*1–3*) with precision sufficient to permit the morphological analysis of color-specific contacts by some second-order neurons (*4*). Since all primate cones are morphologically identical according to present criteria, a comparable analysis of color-specific connections in primates has not been possible. Psychophysical data concerning the spatial properties of primate color processing are available, and large samples of spiking retinal and brain neurons with inputs from cones are being accumulated. Knowing the proportions and densities of cone types at various retinal loci might reveal how the cone mosaic relates to psychophysical performance and neural organization.

Microspectrophotometry has yielded evidence for three spectral types of primate cones (*5*), each containing a single visual pigment. We shall refer to these as red ($\lambda_{max} \cong 575$ nm), green ($\lambda_{max} \cong 535$ nm), and blue ($\lambda_{max} \cong 440$ nm) cones. By using histochemical techniques that we used to analyze the color organization of goldfish cones (*1*), we have been able to describe how red, green, and blue baboon cones are distributed.

When cones are bleached by light, they undergo temporary increases in the rate of mitochondrial electron transport, such increases being measurable as increased rates of reduction of nitroblue tetrazolium chloride (NBT) to a blue-violet product (NBT-diformazan) in the ellipsoids of stimulated cones (*1, 2, 6*). Eyes were enucleated under Nembutal anesthesia from dark-adapted (*7*) baboons (*Papio cynocephalus*) in dim light, opened with a semicircular cut below the corneoscleral junction, placed cut-side down on a pad saturated with iced Locke's saline inside an oxygenated lightproof cannister, and further dark-adapted for 30 minutes. Retinas were removed in infrared light ($\lambda > 800$ nm) through the use of infrared image converters and were mounted receptor-side up on a wax support. The retinas were moistened with Locks's saline (room temperature), oxygenated, and stimulated for 5 minutes with white light ($>10^7$