BEHAVIOR

The Importance of a Well-Groomed Child

Robert M. Sapolsky

It is a rare parent of a newborn who does not feel a panic built around the consequences that her or his actions now have. Developmental studies have indicated that the quality, quantity, and timing of infant stimulation can have long-lasting effects—and soon the anxious parent is convinced that one lullaby sung off-key ensures that a child will not only one day be a sociopath, but will also never use dental floss. If mothers of newborn rats harbor similar anxieties, a report by Liu and colleagues (1) affirms their worries: The authors show that subtle stimulation in a rat's infancy has marked consequences that are probably life-long.

More than 40 years ago, Seymour Levine and his colleagues uncovered the effects of "neonatal handling" (2). Human handling of newborn rats for 15 min daily during the first few weeks of life produced salutary neuroendocrine, neurochemical, and behavioral changes in the adult. However, rats handled at later points in time did not produce the same changes (3). One of the most interesting changes was the decreased secretion of glucocorticoids. These hormones are released by the adrenals during stress, and glucocorticoid excess can have numerous deleterious effects. These include damage to the nervous system, where chronic glucocorticoid excess can accelerate the loss of certain classes of neurons during aging. And indeed, handled rats do have less neurodegeneration and fewer cognitive deficits in old age (4).

Some mechanisms underlying the handling effect on glucocorticoid secretion have been uncovered (3). Handling triggers thyroid hormone release, which appears to activate ascending serotonergic projections into the hippocampal region of the brain. Serotonin can cause long-lasting increases in glucocorticoid receptor number in hippocampal neurons. The hippocampus helps to mediate negative-feedback inhibition of subsequent glucocorticoid secretion, and the higher receptor density enhances the sensitivity with which the hippocampus detects circulating glucocorticoid levels, resulting in more tightly regulated feedback inhibition.

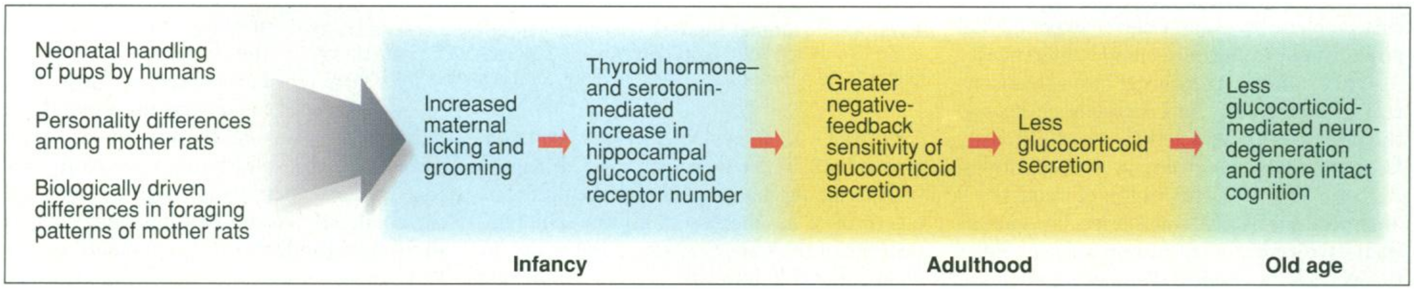
An obvious question is whether handling is relevant to humans. When we reported the decelerated brain aging in handled rats many masseuses wanted to know if they could claim that massages prevented Alzheimer's disease. A less obvious question is what handling means for rats. Levine speculated that it was not the handling that caused the changes, but the behavior of the mother. Specifically, he theorized that the burst of licking and grooming of her pups upon their return to the fold caused the subsequent changes (5). The current report supports this idea.

The authors showed that handling approximately doubled a mother's rate of licking and grooming. They then examined mothers of nonhandled controls and identified approximately a third of the mothers who naturally licked at the same high rate as that induced by handling. Pups of such high lickers-groomers were followed into adulthood and, when compared with offspring of low lickers-groomers, had the same changes induced by handling—less glucocorticoid secretion during a stressor and a faster recovery to baseline afterward, more hippocampal glucocorticoid receptors, and lower hypothalamic corticosteroid releasing factor (CRF) mRNA levels (CRF being the hormone that ultimately controls the release of glucocorticoids). Other changes occurred that were identical to those seen in neonatally handled rats: more open-field exploration (an indication of less anxiety in animals) and more receptors throughout the brain for benzodiazepines (anxiety-reducing tranquilizers) (6).

Obviously, mothering style can influence an offspring's development, but few have shown differences this subtle to be associated with so global a change, or uncovered intervening physiologic steps in the process. Far more remains to be done. First it is to determine whether licking and grooming are indeed critical to the changes that occur in handled rats, or are correlates of even subtler individual differences in mothering style. Next one must show how mothering differences initiate neurotransmitter and receptor changes in the hippocampus. Of potential relevance, tactile stimulation by mother rats maintains growth hormone and ornithine decarboxylase levels in pups (7). One must also test whether some intrinsic feature of a rat that predisposes it to the "handled" profile in adulthood also elicits more maternal behavior when it is a pup. And finally, it must be determined whether the offspring of high lickers-groomers are spared some neurodegenerative ravages of senescence.

The authors suggest that their finding may be ecologically relevant. Various rodent species differ in their storage patterns: a single cache in their burrow or in scattered and distant caches. Although it has been assumed that a genetic difference underlies this behavior, it could also be driven by the organizational effects. Rodents in the latter category have larger hippocampi and better spatial skills (8). The assumption has always been that this represents a genetic difference; instead, it might be driven by the organizational effects of different foraging patterns (for example, how often an animal leaves and then returns to the burrow) on mothering style.

Finally, these findings should have relevance even closer to home. Although the specifics of licking and grooming do not extend to humans, the broader point emphasizing the importance of early experience cer-



Early care counts.

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tainly does. We are in an era filled with parental quandaries such as the type of daycare to provide, the inner-city specter of the dissolution of the family, teen pregnancy, and low government spending on child-related social services during critical periods of brain development. This current study must spur on work examining how early experience alters the trajectory of our own development.

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GEOSCIENCE

Southern California Deformation

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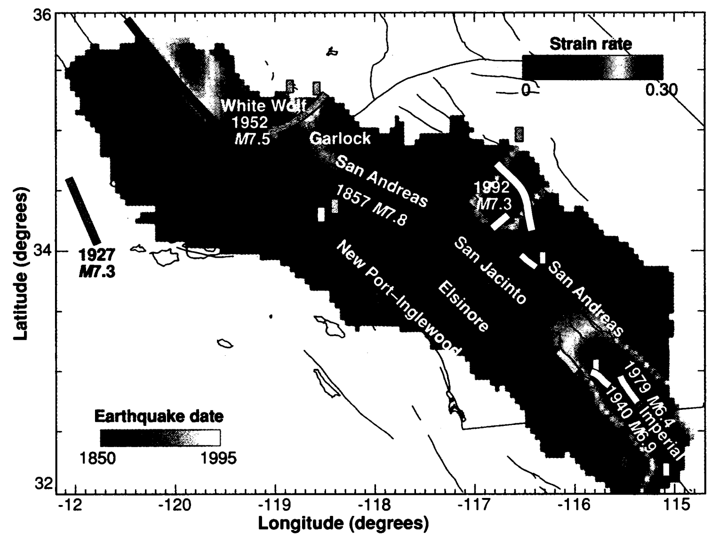
After the 1906 San Francisco earthquake, H. F. Reid discovered that triangulation surveys made before the earthquake revealed substantial deformation in a broad zone surrounding what we now call the San Andreas fault. On the basis of those observations, Reid developed his "elastic rebound" theory, which has motivated the study of crustal strain by modern geodetic methods. Laser measurements of line length and position measurements made with very long–baseline interferometry (VLBI) and the Global Positioning System (GPS) are now common. From these measurements, scientists can identify faults that lack clear evidence of surface deformation, determine the rate of motion on faults for which surface displacements from historical earthquakes cannot be attributed to a known time interval, and test whether today's slip rates on major, well-studied faults are the same as those determined from geological studies. Combined with detailed models relating earthquake occurrence to strain and stress accumulation, such geodetic observations may also help to identify the places where earthquakes are most likely in the next few decades.



Maximum horizontal strain rates in southern California (in microradians per year; see the color scale at top right). Black curves denote the faults and coast and state boundary lines. Gray squares and thick gray curves represent epicenters and surface rupture traces of past earthquakes over magnitude 6. The degree of grayness reflects the time elapsed since that earthquake.

The Southern California Earthquake Center (SCEC) is collecting and interpreting geodetic survey data for southern California to monitor fault motions and earthquake potential. A major product of the study is a set of deformation velocity estimates for 287 sites in southern California that reveal the horizontal component of the crustal deformation resulting from fault motion and viscous flow below depths of about 10 km (*1*).

The study uses laser data collected by the U.S. Geological Survey and other agencies since 1970, VLBI data from the National Aeronautics and Space Administration since 1980, and GPS data from many government agencies, universities, and private companies since 1986. Because geodetic survey data measure relative positions or lengths between sites, most of the data had to be reprocessed to assure that assumptions made in linking individual survey projects were consistent. Because the velocities are intended to reveal the "interseismic" deformation field (between earthquakes), displacements directly attributable to the earthquake ruptures had to be removed from the data. In the affected areas, data from after the 1994 Northridge earthquake and before the 1987 Whittier Narrows and 1992 Landers earthquakes were discarded. In marginal regions, models of earthquake displacements were used to correct for any possible seismic disturbances.

The resulting map of deformation velocities (*2*) on a plate-boundary scale is so accurate and spatially dense that strain rates can be determined directly. The velocity data have revealed that geodetically determined cumulative deformation across the plate boundary agrees well with the long-term deformation predicted by plate tectonic theory (*3*). After resolving the displacements onto individual faults, we find reasonable agreement with geologically estimated fault slip rates (*4*). This agreement implies that present crustal deformation between earthquakes is relatively steady, not deviating much from its long-term average rate (here "long-term" refers to thousands of years, the age of datable features displaced by faults). Such agreements are comforting because modern seismic hazard estimates usually assume that immediate (years and decades) earthquake potential is proportional to the long-term slip rate on faults.

In spite of the overall agreement between short- and long-term rates, the spatial distribution of the present strain rate is still surprising. The figure shows a map of maximum horizontal shear strain rate, faults, and the rupture zones of major earthquakes. The regions of highest shear strain rate are not on the major faults as would be expected, but rather (with one exception) they are in the regions surrounding previous earthquakes. Earthquakes in 1992 [Landers, magnitude (M) 7.3], 1979 (Imperial Valley, M 6.4), and 1952 (White Wolf, M 7.5) have apparently caused the largest "strain reactions." Older earthquakes, in 1927 (M 7.3) and 1857 (M 7.8), have left only subtle imprints on today's strain rate. In general, the earthquakes with ongoing aftershock sequences are those with noticeable strain effects. The only "hot-spot"

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