FALLOUT AND THE DECLINE OF SCHOLASTIC APTITUDE SCORES

by

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Despite a major effort to identify the causes of the significant decline in the Scholastic Aptitude Test (SAT) scores in the United States that began in the 1960s (Wirtz, 1977), no single factor or combination of factors has so far been identified that could adequately explain the observed pattern of temporal and geographic changes.

Among the psycho-social causes considered by the Wirtz Report, the following are believed to have played a part in the decline:

a. Changes in the mix of students taking the tests, more blacks and more women, and more individuals intending to go to less prestigious colleges

b. Changes in curricula and standards in response to the changing type of student

c. Diminished seriousness of purpose and reduced attention to the mastering of basic skills and knowledge

d. A gradually increasing grade inflation

e. Excessive television viewing

f. A rising number of broken homes

g. A general reduction in student motivation

h. Growing national turmoil associated with the urban ghetto riots and the Vietnam war

On the other hand, the various studies commissioned by the Wirtz Committee concluded that the following factors are not likely to have played a significant part in the decline:

a. Cultural bias

b. Differences in predictive ability of the tests for whites and blacks

c. Changes in the difficulty of the test

d. Tests getting out of line with secondary or post-secondary school practices and standards

One other possible cause was briefly considered but rejected: a medical reason (Arnold, 1977) resulting from some change in delivery practice during the birth of the test-takers such as increased use of induced labor that might have caused sufficient brain damage to be a factor in the decline of SAT scores some seventeen to eighteen years later.

However, the paper by Arnold did suggest the possibility that the observed pattern might be explained if there had been a wide-spread ecological factor that began to have an effect on the infant in utero or the newborn in the early post-war years that increased during the following fifteen years. If so, the article spelled out the conditions that it would have had to meet:

a. It would have had to act during early development or childhood and be "sub-clinical" in nature so as to escape early detection.

b. It would have had to be very widely distributed throughout the United States.

c. It would have had to be introduced in 1945-46 in order to explain the decline that began in 1962-63 some seventeen years later.

d. It would have had to increase gradually in its action to explain the accelerating decline during the 1970s.

e. It would have to be of such a nature as to affect test-takers in the most recent years less severely than in earlier years, and it would have to affect present students in grades 3 to 11 less than in the past.

The article considered such factors as pesticides, herbicides, food-additives, drugs, changes in dietary habits, alcohol, cigarettes or diagnostic x-rays during pregnancy, all of which are known to be capable of producing adverse effects on the developing infant in utero.

Largely because these environmental factors continued to act essentially unchanged throughout the late 1950s and the early 1960s when the most recent test-takers were born, Arnold concluded that none of the known biological or environmental factors met the criteria listed by him, leading him to the conclusion "that the decline in SAT scores is not likely to result from physical environmental factors".

However, one widely distributed environmental factor introduced at the end of World War II in 1945 was not considered by Arnold, namely fallout from nuclear weapons tests. Furthermore, unlike all other physical factors, it ceased to be introduced into the environment at the end of the 1950s when a temporary moratorium on all nuclear testing began in 1959, followed by a permanent end to all atmospheric tests by the United States, Russia and the United Kingdom in 1963. It is therefore the purpose of the present paper to investigate the hypothesis that this neglected physical agent in the environment may have played a major role in the decline of SAT scores.

If radioactive fallout from nuclear bomb-testing was indeed a primary yet hitherto unsuspected environmental agent involved in the decline of the SAT scores, then it must meet all five conditions spelled out by Arnold.

First, since the radiation doses to critical organs of the infant just before and after birth have generally been of the order of the relatively small doses received in the course of diagnostic examination of the abdomen in the course of pelvimetry (Lapp, 1962), (Sternglass, 1963), their effect would indeed be subtle and therefore "sub-clinical" so as to escape early detection.

Secondly, atmospheric fallout was a world-wide phenomenon and therefore meets the requirement of wide distribution.

Thirdly, since nuclear fallout began with the first detonation of a nuclear bomb in Alamogordo, New Mexico on July 16, 1945, followed by the detonation of two more bombs in Hiroshima and Nagasaki in August of 1945, fallout meets the criterion of introduction in the time-period 1945-46, needed to explain the decline of test scores beginning in the early 1960s.

Next, the concentration of fallout in the environment increased gradually throughout the post-war period as the total kilotons detonated rose steadily throughout this period until the test-ban came into effect in 1963. In particular, the total amount introduced into the world's atmosphere rose more rapidly with the beginning of hydrogen bomb tests in the Pacific and Siberia beginning in 1952-53 (U.N. 1959, 1962, 1969).

Finally, it meets the requirement that the most recent test-takers as well as young children in the lower grades during the last few years were less seriously affected. The reason is that world-wide levels of fallout began to decline steadily shortly after the test-ban treaty ended atmospheric bomb tests by all nations except France and China, with French atmospheric tests ending in the mid-70s.

Although nuclear fallout meets all the minimum conditions laid down by Arnold, it is desirable to refine these criteria further in order to separate nuclear radiation from the effect of all the other possible physical and psycho-social environmental factors that have been suspected to play a role in the decline of the test scores. The more specific requirements that must be met by this hypothesis are the following:

1. There should be a delay of 17 to 18 years between the onset of a major nuclear bomb test series and a decline in SAT scores, and similarly the same delay must exist between the end of a major nuclear test-series and leveling off in the decline of the scores.

2. Geographically, the greatest declines in SAT scores should have occurred in areas that received the largest fallout doses. These would be either areas closest to the test-sites in Nevada, the Pacific or Siberia, or areas of heavy rainfall in the path of fallout clouds since about 90% of world-wide distance fallout is brought down by precipitation (U.N. 1959). Since rainfall is enhanced by the presence of air pollution (Changnon, 1979), urban areas would in general be expected to be more strongly affected than nearby rural areas in the path of the fallout clouds, quite aside from the compounding effect of other socio-economic factors and chemical agents present in heavily urbanized areas that would be expected to act synergistically with the biological effect of radioactive fallout.

Turning first to an examination of the change of SAT scores with time, (Table I), Fig. 1 shows the trend of the mean verbal SAT scores in the United States for the birth years 1940 to 1960 (SAT years 1958 to 1978), together with a plot of the cumulative external gamma radiation dose from fallout as measured in New York for the period 1949 to 1969 (Hull, 1970), plotted according to birth-year of the test-takers. Since Table I shows that the mathematical scores follow the same general pattern as the verbal scores, the subsequent discussion can be simplified by focusing on the latter set of data.

Inspection of Table I and Figure 1 shows that during the period 1940 to 1945 when there was no fallout, the verbal SAT score remained essentially constant between 472 and 478, fluctuating by only ± 3 points around a mean of 475. Beginning in 1946, there was a steady decline in every year until the testing year of 1976, when the test-score suddenly leveled off at 429.

It is also seen that the rate of decline sharply accelerated in the birth years 1953 and 1954, following the detonation of the first large hydrogen weapons in the Pacific and Siberia, as well as the detonation of a series of small tactical A-bombs at the Nevada test-site beginning in the period 1951-53.

The largest drop in SAT scores is seen to have occurred for the individuals who took the tests between 1973 and 1976, or those who were born between 1956 and 1959. These were the years that showed the largest increases in the cumulative fallout dose recorded up to that time, corresponding to the largest nuclear bomb test series both in Nevada, the Pacific, and Siberia before the temporary test-moratium came into effect at the end of 1958 (Glasstone, 1962).

Following the sharp changes in fallout dose and SAT scores, there occurred the equally dramatic, sudden halt in the decline for the testing years 1976-77 and 1977-78, paralleling exactly the sudden halt in the rise of accumulated fallout dose when nuclear bomb testing came to a temporary halt 17 years earlier in 1959.

Since the U.S.-U.S.S.R. atmospheric bomb tests were resumed in the fall of 1961, it would be expected that the present level trend in the SAT scores will not continue beyond the SAT tests of 1978. One would then expect to see another period of sharp decline as indicated in the dotted curve of Fig. 1, corresponding to the sharp rise in the cumulative fallout dose between 1961 and 1964, followed by another plateau in the SAT scores some time after 1982.

Turning to a more detailed examination of patterns of temporal changes of the SAT scores during the period of heaviest nuclear testing in Nevada closest to the U.S. population centers, one can examine the annual changes grouped by graduating high school class (Table II) rather than the year when the tests were taken (Jackson, 1976). It is then possible to compare the annual changes in verbal SAT scores with the annual additions of radioactive isotopes to the environment as measured by the announced kilotons of equivalent TNT detonated in Nevada 18 years earlier when the test-takers were born (Glasstone, 1962).

Fig. 2 is a graphical representation of the data in Table II, comparing the mean verbal SAT scores by years of high school graduation with the year-by-year kilotonnage of nuclear weapons detonated at the Nevada test-site 18 years earlier. It shows that the greatest declines in scores occurred for the years of largest weapons yields, the decline suddenly ending in 1976, corresponding to the sharp decrease in kilotons detonated in 1958.

A comparison of the annual declines in SAT scores from Table II with the annual weapons yields in kilotons is shown in Fig. 3. Note that the declines in SAT scores are strongest in the years of the greatest weapons test-yield, and least in the years when no weapons were tested at all.

Thus, the detailed comparison of the SAT score declines grouped by graduating class with the known yearly production of fission products in Nevada when the average test-taker was born agree with the long-term correlation between SAT score decline by testing year and the annual changes in the measured fallout radiation dose. It therefore appears that fallout radiation exposure in utero or in early infancy was accompanied by declines in the SAT scores some 17 to 18 years later.

Table III addresses itself to the pattern of geographical distribution in SAT declines. When grouped by regions as presently available by high school classes (Jackson, 1976), the greatest drops during the period of sharpest decline (class of 1974 to 1976) occurred not in the large urban areas of the mid-West, Middle-Atlantic and New England areas, but in the far West, closest to the Nevada, Pacific and Siberian test-sites. While the Mid-West declined 8 points during the birth-year period 1956-58 bracketing the year 1957 of largest Nevada testing, the Western Region from Alaska and Hawaii to Wyoming and Colorado declined 19 points, consistent with the hypothesis that proximity to the test-sites or high rainfall downward from the point of detonation should lead to the largest decline, while locations of low rainfall should show small declines. This hypothesis is further supported by the fact that the second lowest decline of 11 points took place in the dry South-West, to the south of the Nevada test-site and out of the path of the major fallout pattern that was oriented generally towards the North-East (U.N. 1959). New England, with its greater rainfall but greater distance from Nevada and the Pacific was next with a drop of 12 points, followed closely by the South (13 points) and the Middle Atlantic states (14 points) that include the most densely industrialized and therefore most heavily polluted areas such as Pennsylvania, New York and New Jersey.

Thus, none of the heavily urbanized areas in the United States showed a drop as great as the relatively non-urbanized and less heavily industrialized areas of the far West which include Hawaii, Alaska, Washington, Oregon, Montana, Idaho, Wyoming, Colorado, Arizona, California, Utah and Nevada, again supporting the hypothesis that bomb fallout is the previously neglected environmental factor involved in the sharp decline of SAT scores in the United States.

A more detailed test of this hypothesis was possible as a result of the availability of some state-by-state data on radioactivity in the milk beginning with the measurements carried out by the U.S. Public Health Service in 1957 (Campbell, 1959) and corresponding state-by state data for the SAT tests (Jackson, 1976). Beginning in June 1957, the Public Health Service reported monthly measurements of both the short-lived radioisotopes Iodine-131 (Half life 8.1 days), Barium-140 (Half life 12.8 days) and Strontium-89 (Half-life 53 days) as well as the long-lived isotopes Strontium-90 (Half-life 28 years) and Cesium-137 (Half-life 33 years) in the milk for certain metropolitan areas in 5 states. These were Sacramento, California; Salt Lake City, Utah; St. Louis, Missouri; Cincinnati, Ohio and New York City, New York.

The SAT data for four of the five states were available (College Board, 1979), namely California, New York, Ohio and Utah for the high school classes of 1972-73 to 1976-77, which bracket the years of the largest decline, 1973-74 to 1975-76. This set of data may be found in Table IV, along with the changes between the 1974 and 1976 high school classes. The largest drop for this two year period bracketing the birth year 1957 occurred in Utah, where the decline was 26 points, compared with 2 points in Ohio two thousand miles to the east of the test site. The decline in Utah was higher than the 19 point drop for the Western Region as a whole and the 20 point drop in California, consistent with the close proximity of Utah to the test site and the general north-eastward motion of most of the fallout clouds produced by the Nevada tests.

New York dropped by 17 points, an amount intermediate between that of Utah and Ohio. This is consistent with the higher rainfall and the compounding factors of urban air-pollution, drug use, and other physical and psycho-social problems in New York City compared with more rural Ohio.

Although the available radioactivity data for milk were not gathered on a state-wide basis and therefore are not strictly comparable with the state-wide SAT scores, they support the hypothesis that fallout levels were much greater in Utah than for instance in New York. Thus, Table 2 (Campbell, 1959) gives an average concentration of Iodine-131 for the period June 1957-April 1958 of

249 pCi/liter of milk in Salt Lake City, compared with an average of only 79 pCi/liter in New York City. A comparison with Sacramento, which has a relatively low annual rainfall and is located far to the north of Los Angeles does not provide a good measure of the milk, air and dietary levels in Southern California closest to the test-site, but it does show a lower level of short-lived isotopes than Salt Lake City in accordance with the present hypothesis. Thus, the average concentrations for Iodine-131, Barium-140 and Strontium-89 were 30.0, 19.7 and 21.2 pCi/liter in Sacramento compared with 249, 49.1 and 30.5 pCi/liter respectively in Salt Lake City.

To summarize these findings, both the temporal and geographical patterns of the changes in SAT scores are consistent with the hypothesis that radioactive fallout from nuclear weapons testing in Nevada, the Pacific and Siberia exerted a significant influence on the mental development of infants in utero at the time of heaviest nuclear weapons testing.

The observed sharp decline in SAT scores followed by an equally sudden halt some 17 to 18 years after the largest weapons tests, together with the fact that the greatest changes took place nearest to and downwind from the Nevada test site, where the intense short-lived radioactivity had an opportunity to pass through the food chain before it decayed away, points to nuclear fallout as the most important environmental factor involved in the observed changes in the SAT scores. Such rapid, localized fluctuations cannot be readily explained by excessive television viewing, long-term changes in school curricula, gradual changes in the type of student taking the tests, diminished seriousness of purpose of the students or teachers, grade inflation, broken homes, student motivation or national political turmoil as suggested by the Wirtz Commission, although any or all of these factors could clearly aggravate the problem in a synergistic manner.

Similarly, the effect of toxic environmental agents other than fallout such as drugs, cigarettes, alcohol, air-pollution, automobile exhaust, pesticides, herbicides, medical x-rays, or changes in obstetrical practices during delivery could not, by themselves, explain the sudden drop in scores followed by an equally sudden end to the decline since they continued to act essentially unchanged when bomb testing was briefly halted between 1959 and 1961. Nor is there any evidence to suggest that these factors should be concentrated in the Western United States, and in particular in Utah, where the Mormon religious customs have in fact resulted in very low per capita consumption of cigarettes (Tobacco Tax Council, 1971).

In support of the hypothesis that fallout was the new, widespread environmental agent that began to affect the children born after 1945 to a steadily growing degree, evidence exists that childhood leukemia (Lyons, 1979) and thyroid abnormalities (Weiss, 1967), rose significantly in Utah for the children in utero during this period. Such effects had not been thought possible as the relatively low radiation doses involved until the discovery of Stewart and Kneale (Stewart, 1970) that the embryo and fetus in some ten to one hundred times more sensitive to the induction of childhood leukemia and other cancers by a few diagnostic x-rays of comparable dose than the middle-aged adult, the sensitivity decreasing with the stage of intra-uterine development.

Not only did childhood leukemia and thyroid abnormalities rise in Utah following the Nevada tests, but so did infant mortality for all causes of death. From a minimum of 20.4 per 1000 live births, the mortality rate rose to a peak of 22.1 in 1958, decreasing again to 19.6 by 1960 when nuclear testing was temporarily halted between 1959 and 1961 (U.S. Vital Statistics). This rise of 8.3% is larger than the rise of 4.2% observed for California, 2.7% in New York and 2% in Ohio, paralleling the relative effect on SAT score declines for these states for the children born during the 1955-59 period of weapons testing.

Furthermore, following the end of the atmospheric tests in 1963, infant mortality rates for Utah and the United States as a whole began to decline once more, until in the most recent years, the rate of decline for both white and non-white infants in the United States once again resumed its pre-1950 rate (See Fig. 4). Thus, the temporal pattern of infant mortality changes agrees with the pattern of fallout, kilotonnage detonated, and SAT declines.

More recently, a large-scale epidemiological study at Johns Hopkins University (Diamond, 1973) showed that the risk of death associated with diseases of the central nervous system was significantly increased by relatively small amounts of radiation during intra-uterine development. Likewise, the risk of congenital defects has been shown to be increased by intra-uterine radiation in animal studies as well as in observations of infants accidentally exposed to radiation during intra-uterine development. Since cognitive deficits are far more frequent among individuals with congenital abnormalities, one would expect to find increasing incidence of congenital defects.

Evidence suggesting an increased incidence of congenital defects following the deposition of fallout was first presented by Le Vann for the province of Alberta in Canada (Le Vann, 1963). Although the findings were complicated by the simultaneous introduction of thalidomide into Canada in the early 1960s that acted synergistically to increase the effect of radiation (Sternglass, 1977), LeVann's data showed a greater incidence of congenital defects in areas of higher rainfall, exactly as for the case of SAT score declines discussed above.

The fact that the incidence of congenital defects also rose in Utah following the onset of the Nevada bomb-tests is illustrated by the data for the annual deaths due to congenital defects of children 0 to 4 years old in Utah between 1938 and 1968, together with the number of deaths due to accidents for comparison (Fig. 5), (Sternglass, 1972). The number of deaths associated with congenital defects showed a large peak between 1953 and 1958, followed by a sudden decline in 1959 and 1960 corresponding to the sharp drop in the SAT scores in Utah and a partial recovery after the end of the Nevada tests in 1958. Furthermore, a second peak in 1961-62 corresponds to the resumption of nuclear bomb tests in the fall of 1961, suggesting that a second period of SAT score decline should begin in Utah and to a lesser degree elsewhere in the U.S. in 1979-80. No such clear rises and declines occurred for accidental deaths in Utah for this age group during the same period.

The fact that radiation can produce mental retardation in large human populations exposed to ionizing radiation during intra-uterine development was also emphasized in a report of the United Nations Scientific Committee on the Effects of Radiation published in 1969 (U.N., 1969). Figure 6 represents a plot of the prevalence of severe mental retardation among individuals exposed to the atomic bomb radiation in utero as a function of the radiation dose taken from Table V, p. 86 of the U.N. report. This plot reveals a direct relation between the prevalence of mental retardation as measured by psychological tests at age 20 and the radiation dose received during early development, without any evidence for a safe threshold below which no effect occurs.

It should be noted that the thyroid doses to the fetus and infant in Utah, although relatively small, were within the lower range of doses received by the surviving infants in Hiroshima and Nagasaki namely 1-100 rads (Weiss, 1967).

There is, however, a difference in the duration of the exposure, which was only a matter of seconds at Hiroshima and Nagasaki, while it was protracted over periods of weeks or months in Utah and other areas affected by distant fallout. For this reason, it is of interest that a high prevalence of mental retardation was also discovered in a population exposed to above normal background radiation over long periods of time in Kerala, India (Kochupillai, 1976). Comparing the prevalence of chromosomal abnormalities, Down's syndrome and various forms of mental retardation in two similar fishing villages over 20 miles apart but with large differences in annual background radiation due to natural thorium sands, the results for the prevalence of mental retardation at birth are presented graphically in Fig. 7 for comparison with the data for a brief exposure in Fig. 6.

The dose needed to double the normal incidence in Kerala is about 300 mrads per year, or 12 rads over a period of 40 years. This is not very different in magnitude from the estimate of 15$\pm$5 rads arrived at for the doubling dose in Hiroshima and Nagasaki. The total doses over periods of years are therefore of the same general order as the annual doses to the thyroids of children in Utah during the period of Nevada bomb tests.

As to the nature of the biological mechanism leading to subtle forms of cognitive impairment by fallout, the outstanding fact is that the greatest effects occurred in the Western Region of the United States nearest the Nevada test site. This is an area showing the highest concentration of Iodine-131 and other short-lived iodine isotopes which concentrate in both the fetal and infant thyroid to a much greater degree than in the thyroid of the adult. It suggests that the principal biological effect is one of the growth-controlling hormones produced by the thyroid gland, especially during the last few months of fetal development.

This conclusion finds support in the extensive studies carried out on the Marshallese Island children accidentally exposed to fallout following the 1954 Bravo hydrogen bomb test (Conard, 1965, 1966). There was striking degree of growth retardation associated with hypothyroidism, particularly for the youngest children at the time when the fallout arrived, with doses to the thyroid generally estimated to have been in the range of 10 to 1000 rads. As in the case of the Utah population, there was also an increase in thyroid nodules and thyroid cancer many years later, but the earliest effect was apparently one of hormonal disturbance.

The fact that the SAT scores in Utah and elsewhere in the United States did not return to the levels that existed prior to the onset of nuclear bomb testing as soon as the Iodine-131 disappeared from the environment in 1959 and 1960 suggests that the biological action of the fallout was not solely due to the radioactive iodine on the thyroid gland of the developing infant in utero. There are a number of biological mechanisms that can lead to a cumulative effect such that later-born children show a greater effect than those exposed in the first few years of bomb testing.

Cumulative damage to the ova and the sperm-cells of the parents would provide one possible explanation of effects that increase with time, similar to the Kerela situation, where the reproductive cells of the parents are exposed for many years.

Another mechanism that could bring about a cumulative deterioration of cognitive abilities would be the long-term build-up of radioactive isotopes in the body, particularly the skeleton of adolescent females consuming large quantities of milk. In particular, Strontium-90 has been found to build up in the human body over a period of many years, the biological half-life for elimination from the skeleton being of the order of 5 to 10 years depending upon the age. Not only does the Strontium-90 circulate in the blood, thus contributing to the dose received by soft-tissue organs, but it also transforms itself by radioactive beta decay to the radioactive daughter product Yttrium-90 which has a different chemical valence state than Strontium-90, causing it to accumulate preferentially in critical soft tissue organs such as the pituitary gland and the male and female gonads, (Spode, 1958), (Graul, 1958).

As a result, a young woman who has consumed Strontium-90 that goes along with calcium in the milk and diet will have a steadily increasing amount of both Strontium-90 and Yttrium-90 in her body during the period of weapons testing. If she then becomes pregnant, the newly developing baby, drawing on the mother's reservoir of calcium in her bone, will also receive along with it elevated levels of both the toxic Strontium and Yttrium.

Thus, it is possible that the pituitary gland of the developing infant will be damaged by the beta rays emitted from the Yttrium-90, leading to various degrees of secondary hypothyroidism since the pituitary gland in turn controls the function of the thyroid.

As a result, one would expect growth retardation from the cumulative ingestion of long-lived Strontium-90 by the mother prior to pregnancy, as well as due to the short-lived Iodine-131 going directly to the fetal thyroid. The former would lead to a cumulative effect such that later-born children would experience greater growth retardation than those born earlier in the bomb-testing period, thus explaining the overall decline during the period of weapons testing as indicated by Figures 1 and 2.

The short-lived Iodine-131 would dominate in areas close to and downwind from the site of detonation, especially in the case of small tactical weapons in the kiloton range, where the fireball touches the ground and the resulting heavy radioactive debris descends within minutes or hours in the downwind areas before the short-lived isotopes have had a chance to decay. This is in sharp contrast to the case of megaton bombs detonated well above the surface, where the radioactive debris rises high into the stratosphere and takes many months to reach the ground (Glasstone, 1962).

Since a number of studies have revealed a close correlation between fetal and infant mortality and levels of Strontium-90 in the milk [Sternglass, 1969(a) and 1972(b)], (Lave, 1971), (Bertel, 1979), it is reasonable to assume that for every child that dies in the first year of life, there will be many who survive but who will show minimal or sub-clinical developmental retardation, thus explaining the subtle effects on cognitive functions for individuals who are otherwise free of any obvious congenital defects.

Undoubtedly there exist still other, more complex mechanisms whereby radioactive fallout with its large number of different chemical elements can induce both short and long-term effects on cognitive functions, for instance as a result of an increased susceptibility to infectious diseases that are capable of producing brain damage such as measles and encephalitis.

Whatever the detailed biological mechanisms may turn out to be, the existing evidence for surprisingly large effects of low-level environmental radiation on verbal and reasoning ability as reflected in SAT scores would seem to call for a complete reexamination of our existing standards for environmental radiation that are largely based on genetic and somatic effects for the adult rather than on developmental effects for the much more sensitive infant in utero. An extensive program of epidemiological studies is clearly needed to investigate in detail the effect of past radioactive releases on hormonal functions and cognitive ability in order to evaluate the full impact of world-wide fallout from nuclear weapons, natural background radiation and the releases of radioactive wastes from peaceful nuclear operations into the environment.

Table I

Mean Verbal and Mathematical SAT Scores
By Year of Testing, 1956-57 to 1976-77

SAT Testing Years	Birth Years*	Mean Verbal S.A.T. Score	Mean Math. S.A.T. Score
1956-57	1939	473	496
1957-58	1940	472	496
1958-59	1941	475	498
1959-60	1942	477	498
1960-61	1943	474	495
1961-62	1944	473	498
1962-63	1945	478	502
1963-64	1946	475	498
1964-65	1947	473	496
1965-66	1948	471	496
1966-67	1949	467	495
1967-68	1950	466	494
1968-69	1951	462	491
1969-70	1952	460	488
1970-71	1953	454	487
1971-72	1954	450	482
1972-73	1955	443	481
1973-74	1956	444	478
1974-75	1957	437	473
1975-76	1958	429	470
1976-77	1959	429	468

* Birth years are generally 17 years prior to the earliest year of S.A.T. testing, or 18 years prior to the last test.

Table II

Mean Verbal SAT Scores by Year of High School Graduation
Compared with Kilotons of Tactical Nuclear Weapons Detonated
in Nevada 18 Years Earlier

Year of H.S. Graduating Class	Year of Birth and A-Tests	Mean Verbal SAT Score (U.S.)	Annual Change in Score	Kilotons Detonated in Nevada
1967	1949	466	-	0 kt
1968	1950	466	0	0 kt
1969	1951	463	-3	111 kt
1970	1952	460	-3	104 kt
1971	1953	455	-5	252 kt
1972	1954	453	-2	0 kt
1973	1955	445	-8	167 kt
1974	1956	444	-1	0 kt
1975	1957	434	-10	303 kt
1976	1958	431	-3	18 kt
1977	1959	429	-2	0 kt
1978	1960	429	0	0 kt

Table III

Mean Verbal SAT Scores by Year of Birth and
Year of High School Graduation for California,
New York, Ohio and Utah

Birth Year	California		
1955	1972-73	452	
1956	1973-74	450	
1957	1974-75	435	-20
1958	1975-76	430	
1959	1976-77	427	
	New York		
1955	1972-73	454	
1956	1973-74	454	
1957	1974-75	441	-17
1958	1975-76	437	
1959	1976-77	434	
	Ohio		
1955	1972-73	457	
1956	1973-74	459	
1957	1974-75	456	-2
1958	1975-76	457	
1959	1976-77	459	
	Utah		
1955	1972-73	528	
1956	1973-74	532	
1957	1974-75	516	-26
1958	1975-75	506	
1959	1976-77	515	

Table IV

Changes in the Mean Verbal SAT Scores of High School Graduating Classes 1976 Compared with 1974 by Region*
(Birth Years 1956 and 1958)

	H.S. Class		
New England	1974	447	-12
	1976	435	
Middle Atlantic	1974	445	-14
	1976	431	
South	1974	426	-13
	1976	413	
Mid-West	1974	459	-8
	1976	451	
South-West	1974	444	-11
	1976	433	
West	1974	454	-19
	1976	435	

* The college board regions consist of the following states:

New England: Maine, Vermont, New Hampshire, Massachusetts, Rhode Island, Connecticut
Middle Atlantic: New York, Pennsylvania, New Jersey, Delaware, Maryland, District of Columbia, Puerto Rico
South: Virginia, Kentucky, North Carolina, Tennessee, South Carolina, Georgia, Alabama, Mississippi, Louisiana, Florida
Mid-West: North Dakota, South Dakota, Nebraska, Kansas, Minnesota, Iowa, Missouri, Wisconsin, Illinois, Indiana, Michigan, Ohio, West Virginia
South-West: New Mexico, Texas, Oklahoma, Arkansas
West: Alaska, Hawaii, California, Arizona, Oregon, Washington, Idaho, Montana, Wyoming, Colorado

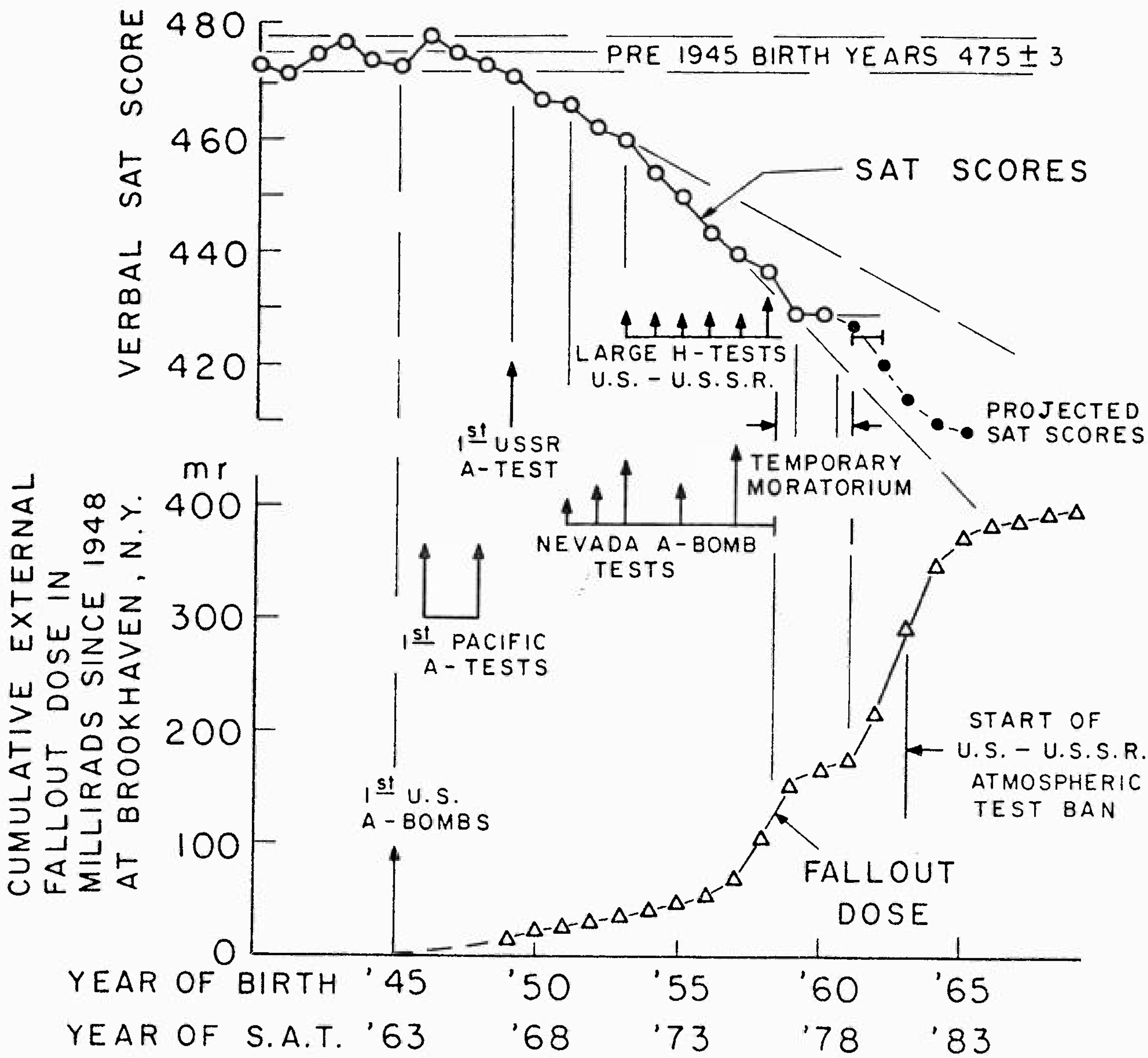

FIGURE 1. TREND OF MEAN VERBAL SAT SCORES IN THE UNITED STATES BY YEAR OF APTITUDE TEST COMPARED WITH THE CUMULATIVE EXTERNAL GAMMA RADIATION DOSE FROM FALLOUT AS MEASURED IN NEW YORK STATE 18 YEARS EARLIER WHEN THE TEST-TAKERS WERE BORN.

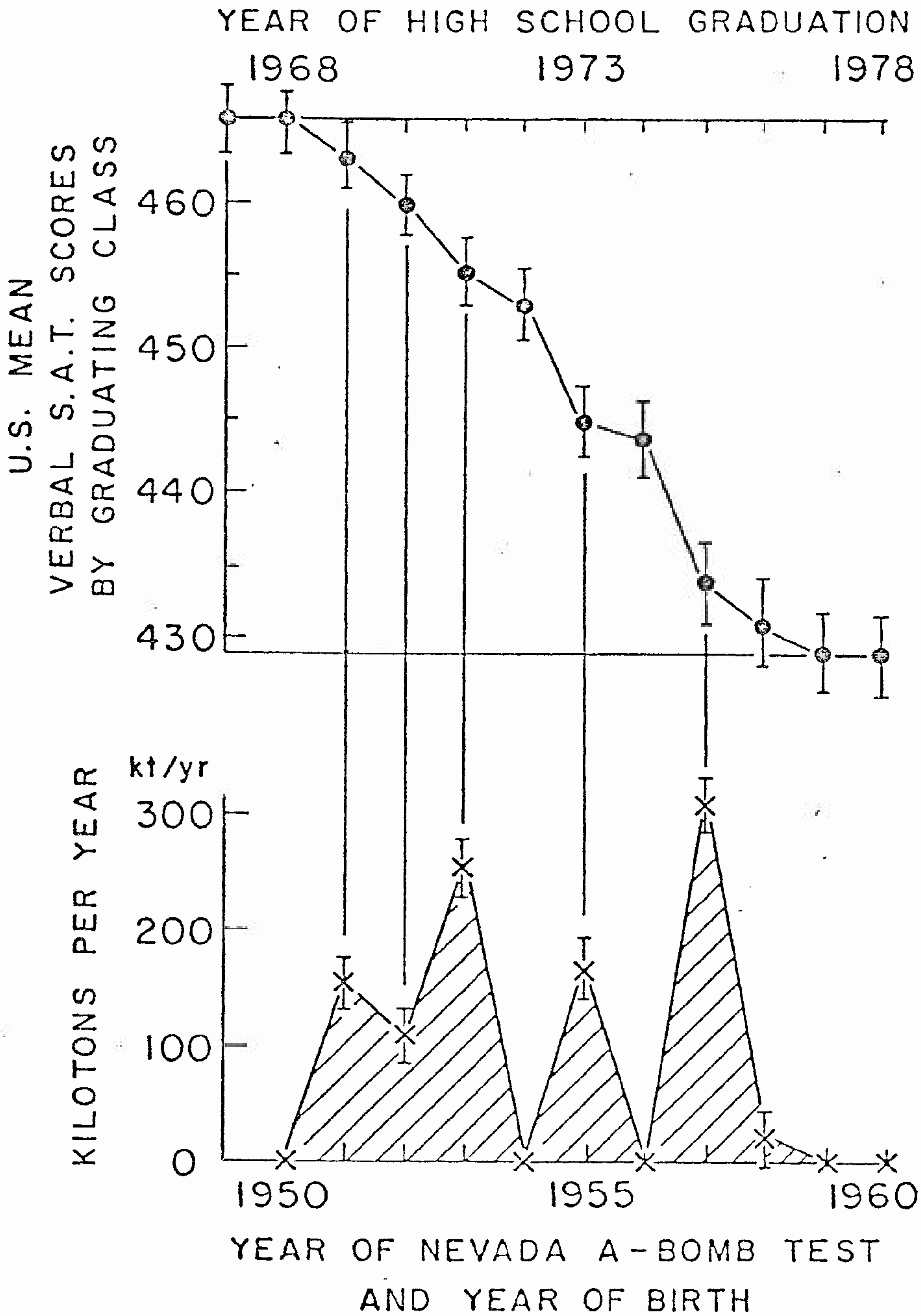

FIGURE 2. TREND IN THE MEAN VERBAL SAT SCORES FOR U.S. HIGH SCHOOL GRADUATES COMPARED WITH THE ANNUAL KILOTONS OF SMALL ATOMIC BOMBS DETONATED IN NEVADA 18 YEARS EARLIER.

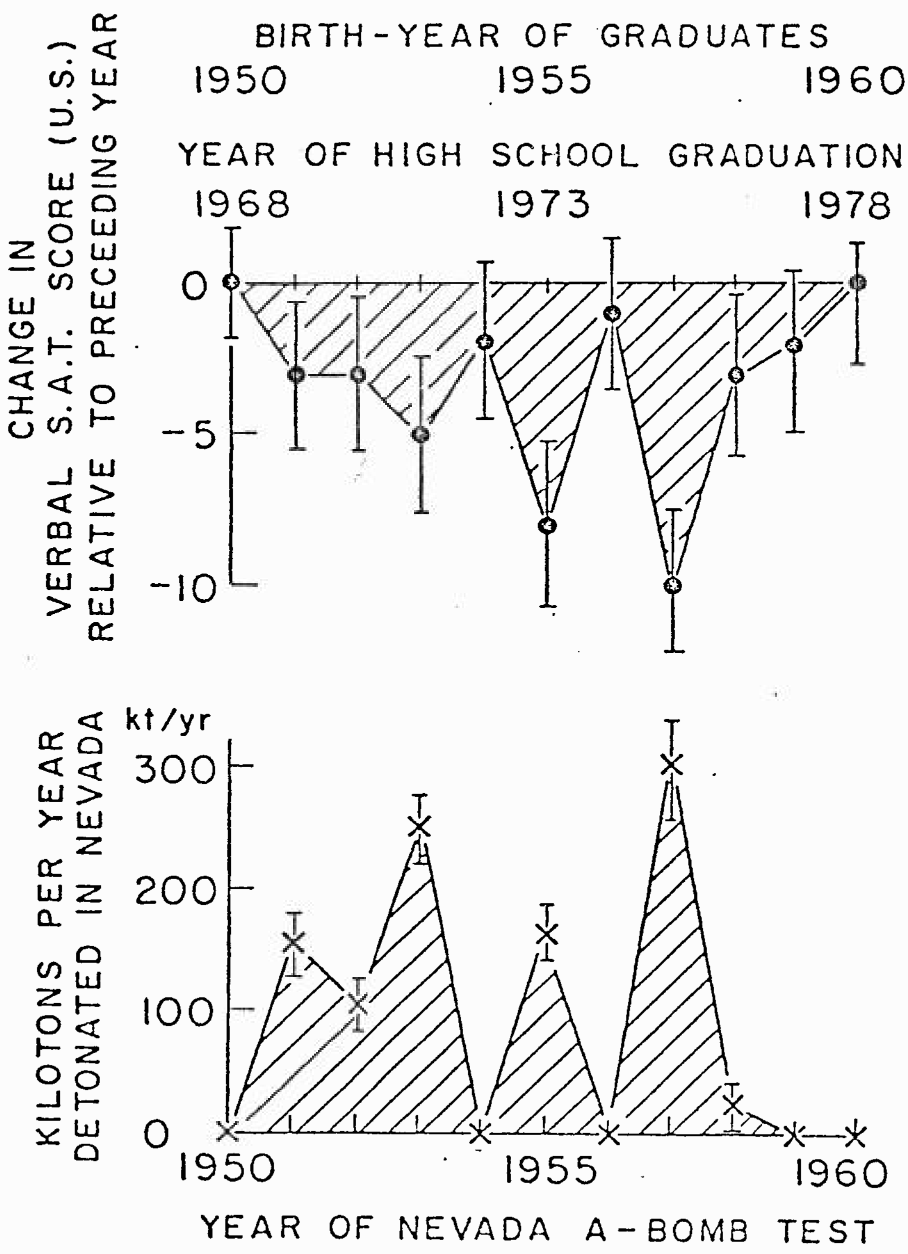

FIGURE 3. ANNUAL DECLINES IN THE MEAN VERBAL SAT SCORES BY YEAR OF HIGH SCHOOL GRADUATION COMPARED WITH THE ANNUAL KILOTONS OF SMALL ATOMIC BOMBS DETONATED IN NEVADA 18 YEARS EARLIER.

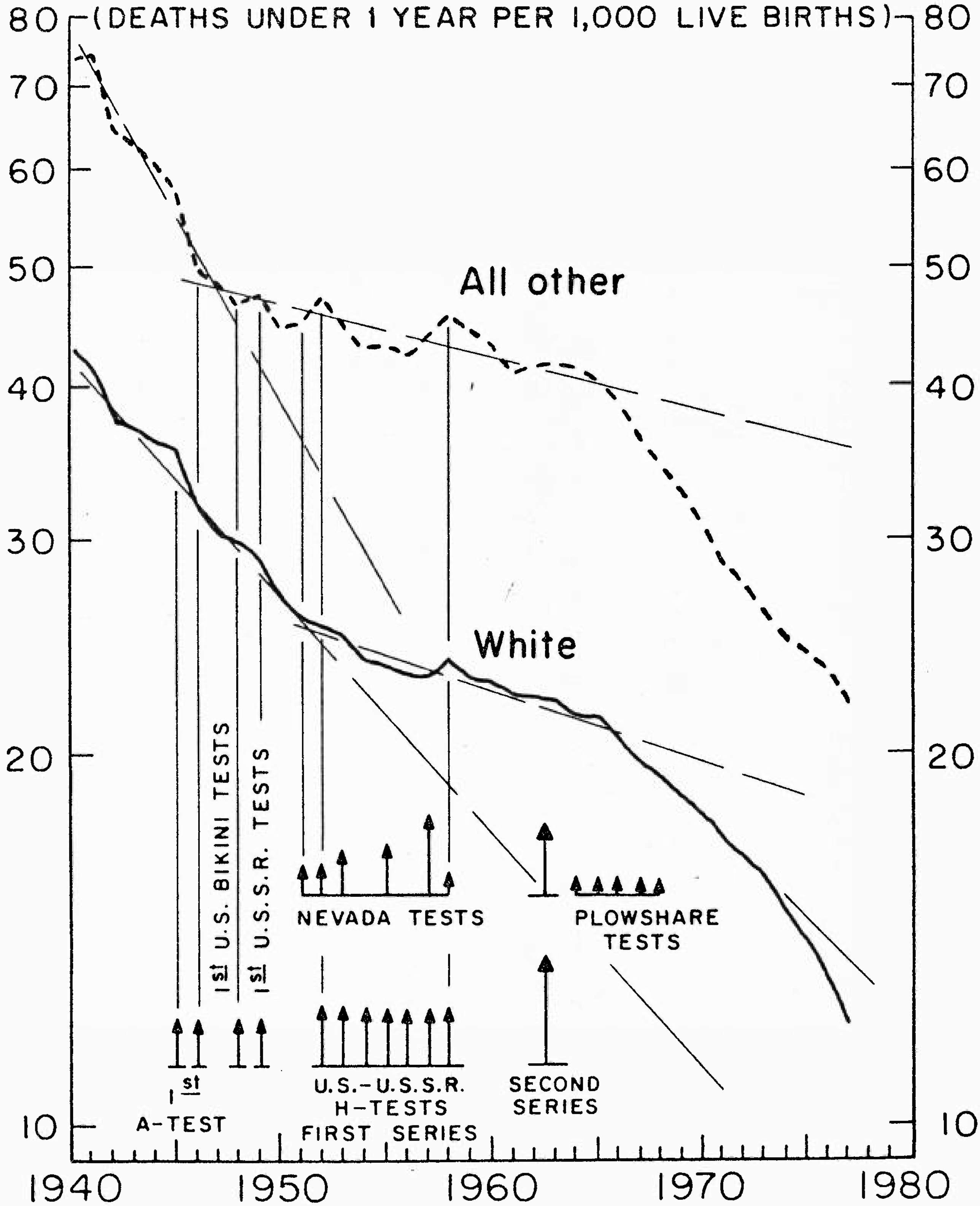

FIGURE 4. CHANGING TRENDS IN INFANT MORTALITY IN THE UNITED STATES FOR WHITE AND NON-WHITE POPULATIONS 1940-77. BEFORE, DURING AND AFTER LARGE-SCALE ATMOSPHERIC NUCLEAR WEAPONS TESTS. DATA FROM U.S. MONTHLY VITAL STATISTICS, VOL. 28, NO. 1, MAY 11, 1979, WITH PERIODS OF MAJOR ATOMIC TESTS ADDED.

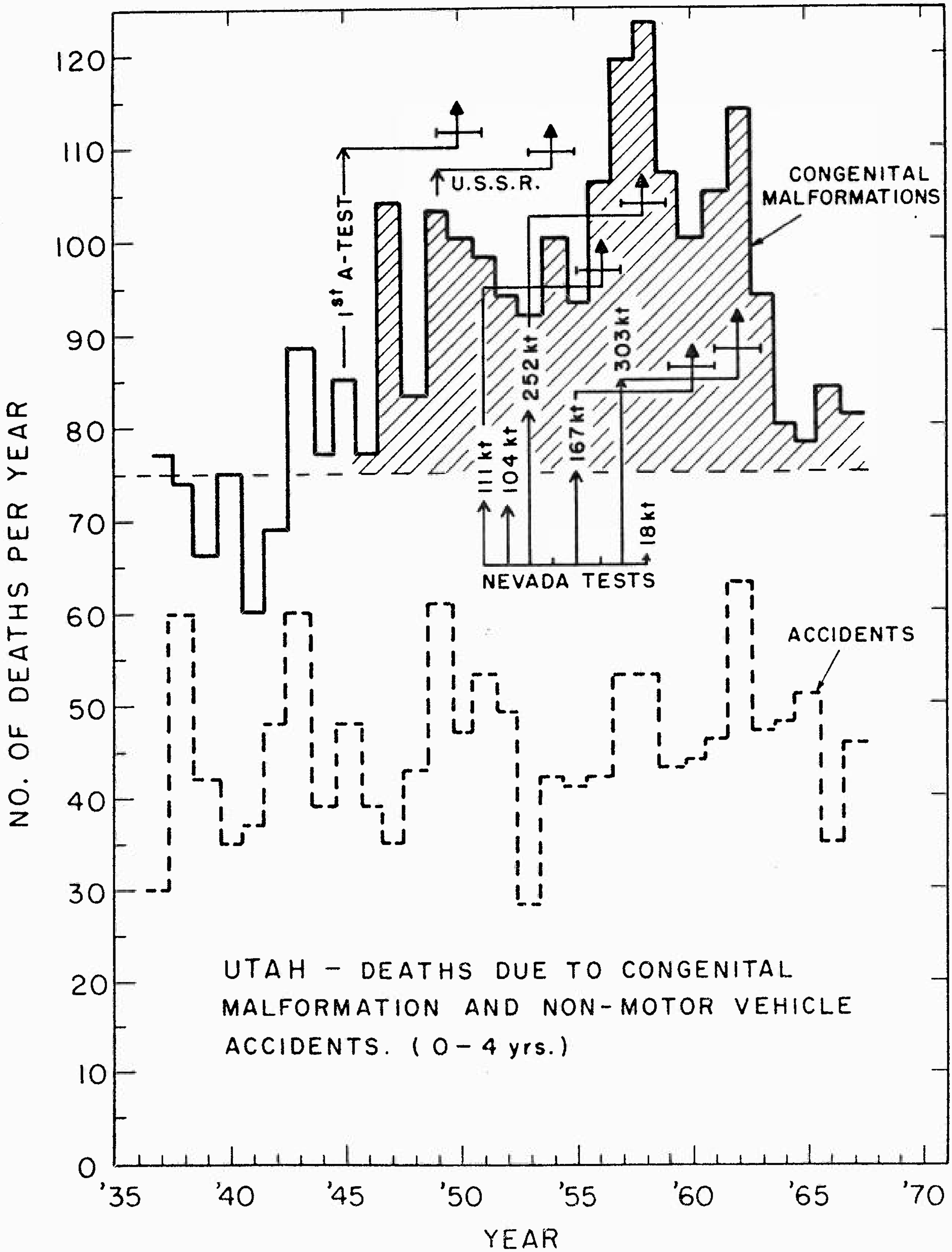

FIGURE 5. ANNUAL NUMBER OF DEATHS PER YEAR DUE TO CONGENITAL DEFECTS FOR 0-4 YEAR OLD CHILDREN IN UTAH, 1938-1967 COMPARED WITH ANNUAL DEATHS DUE TO ACCIDENTS.

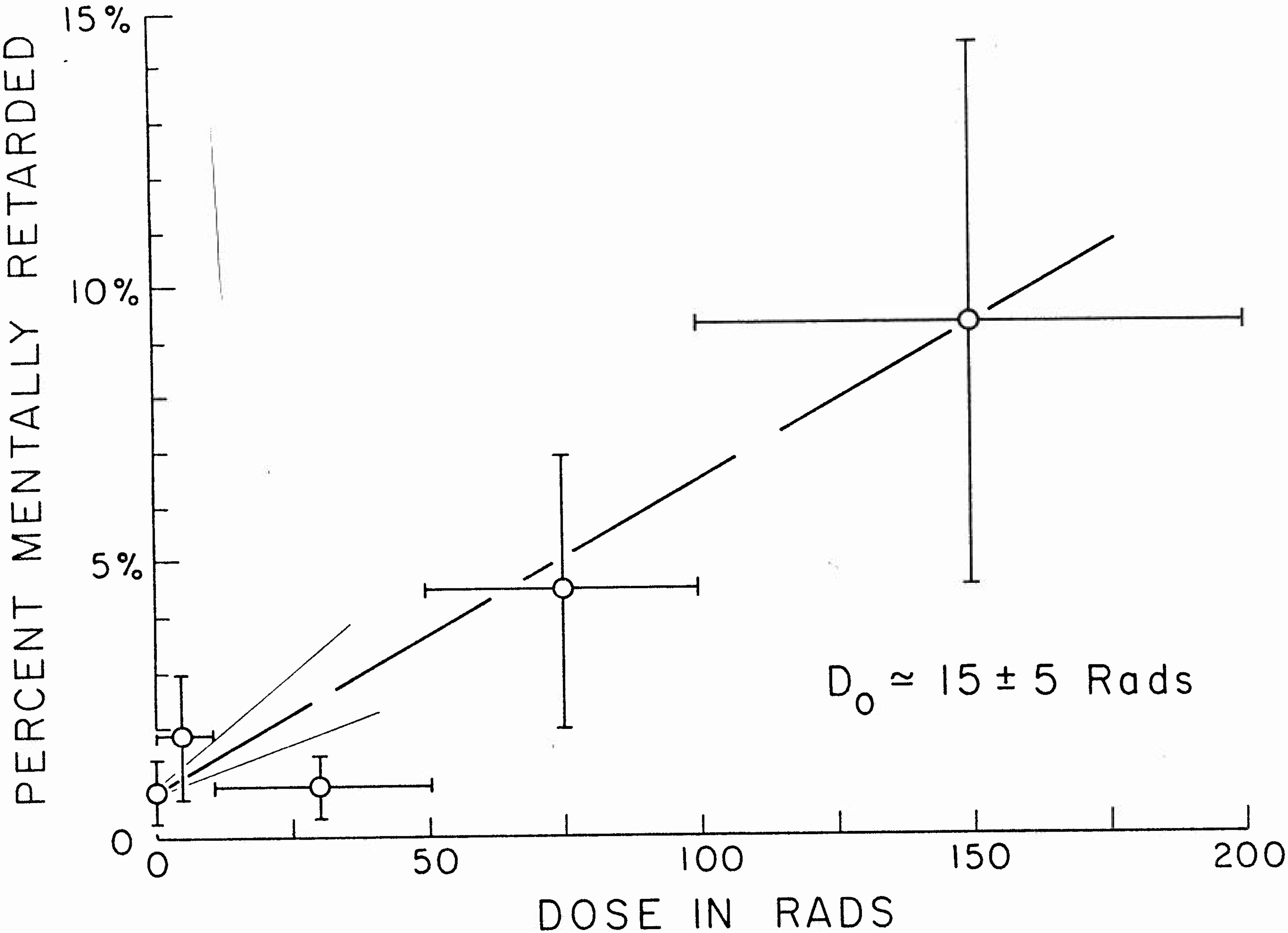

FIGURE 6. INCIDENCE OF MENTAL RETARDATION FOLLOWING RADIATION EXPOSURE IN UTERO IN HIROSHIMA AND NAGASAKI 20 YEARS EARLIER AS A FUNCTION OF DOSE. DATA FROM TABLE V, P. 86, 1969, U.N. SCIENTIFIC REPORT ON THE EFFECTS OF ATOMIC RADIATION.

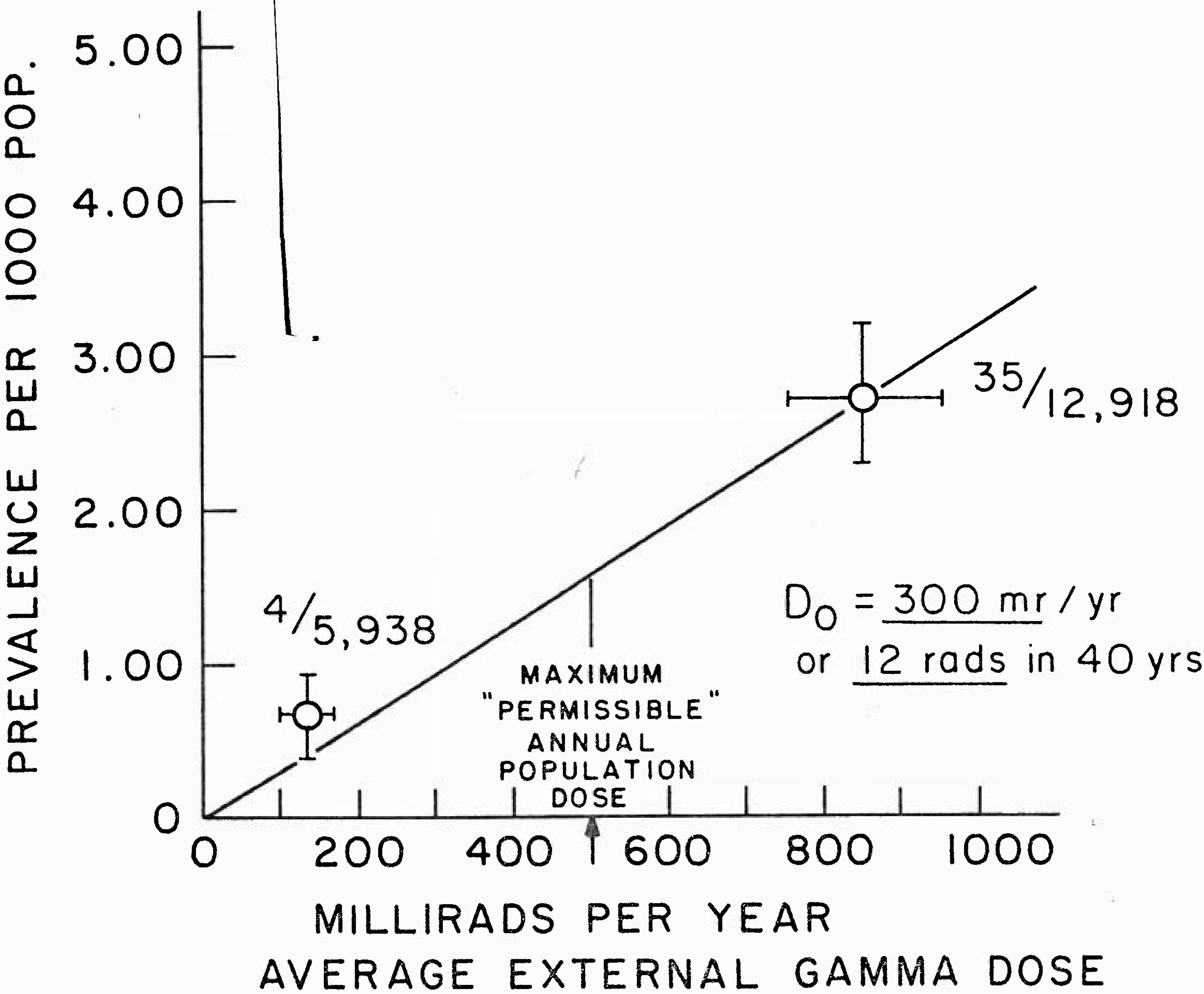

FIGURE 7. NUMBER OF INDIVIDUALS WITH SEVERE MENTAL RETARDATION PER 1000 POPULATION FOR AREAS OF DIFFERENT NATURAL BACKGROUND RADIATION LEVELS IN KERALA, INDIA. THE RADIATION DOSE IS THAT DUE TO EXTERNAL GAMMA RADIATION ONLY AS AVERAGED FOR THE TWO AREAS STUDIED.

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