DOCUMENT RESUME

ED 033 532 EF 002 331

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TITLE A Summary of Some Biochemistry and Thermal Aspects of Intelligence.

Pub Date [50]
Note 7p.
Available from Darell Boyd Harmon, 407-11 Page Building, Austin, Texas

EDRS Price EDRS Price MF-$0.25 HC Not Available from EDRS.

Descriptors *Biochemistry, Child Development, *Classroom Environment, Climate Control, Climatic Factors, Environmental Criteria, *Environmental Influences, *Environmental Research, Heat, Learning, Temperature, *Thermal Environment

Abstract

Because of the intensity factors involved in school tasks, and the importance of schooling in determining the child's future in this complex civilization, the energy organizations and physical limits of the classroom are probably the most significant of all the factors encountered in shaping the child's ultimate social form. Very little is known about the energy aspects of the thermal environment as it affects learning performance. Three basic points on this matter can be identified here--(1) the biochemical make-up of the developing child necessitates a different set of standards for controlling the thermal school environment from those used for adults, (2) because organic function is modified through stress, and action which is induced by any energy organization, the school thermal environment requires more careful control (temperature, air movement, and humidity) to assure promotion of optimum learning, and (3) full rapport in problem-solving situations depends on shifts in internal body temperature and close maintenance of certain body temperature levels: this fact necessitates rigid control to assure optimum learning outcomes. Considerable work is needed to establish the norms of these temperature levels for children, together with their tolerance for variations while engaging in school activities. (KK)

C O - O R D I N A T E D   C L A S S R O O M   L E C T U R E

A Summary of

SOME BIOCHEMISTRY AND THE THERMAL ASPECTS OF INTELLIGENCE

DARELL BOYD HARMON

"The child is inseparable from his environment" has become virtually the first axiom of child development. The realization of the child's potentialities for growth, development, and well-being, and what he ultimately does with the capacities he brings into this world are largely determined by the surroundings in which he is placed. Objectively (and from the physical point of view) his surroundings mean the purposeful and the chance organizations of energies and the physical restraints he meets in his day-to-day environment.

Because of the time and intensity factors involved in the tasks required by the school, and the major place the school now occupies in determining the future of the child in this complex civilization, the energy organizations and physical limits of the classroom are probably the most significant of all those he encounters in shaping the child into his ultimate social form. For optimum learning and development the classroom designer must bring the control of the significant energy organizations of the classroom into a pattern more nearly in keeping with a possible realization of the full potentialities of children during the school aspects of their development.

The energies of biological significance in the classroom fall into two equally important categories; those that induce communication and action (such as light and sound) and, those that affect rapport and the metabolic processes which make purposeful action possible. In this second category are the energy aspects of the thermal environment.

Because of the long-time emphasis in education on communication through speech and the printed word (e.g., approximately 80% of the instruction in school is by visual means or through spoken words interpreting visual experience) research in vision and the control of light, and in audition and the control of sound, has advanced far in relation to our understanding of children and the learning process together with the application of derived principles to design of classrooms.

Very little is known about the energy aspects of the thermal environment as it affects learning rapport and learning performance, as compared to our knowledge of light and sound. Only recently have we learned that rapport in problem solving, for example, is largely derived from body temperature, but we still have to find the norms for maintaining this internal temperature at an optimum for school tasks.

While the effective-temperature scale of the American Society of Heating and Ventilating Engineers may be entirely satisfactory for adult environments --and no question is raised here as to such a use of that scale--a number of factors inherent in the nature of the child and the learning process preclude the unqualified acceptance of that scale as a standard for classrooms. This does not necessarily mean a sweeping rejection of all the quantitative values established by that scale. However, the nature of the child and the critical place the school now plays in his growth, development, and well-being, and in his ultimate success and efficiency, call for a broader emphasis on all the factors of the thermal environment which must be controlled, together with a further determination of additional quantitative values and the equating of all quantitative values with the requirements of the curriculum.

Such a procedure necessitates a preliminary statement of an hypothesis or theory of the physiological bases of regulating the thermal environment of the classroom in order to guide the needed re-formation of emphasis on certain aspects of the control of heating, ventilating, and air conditioning, and the research into added or adjusted values. This paper proposed to make a tentative exploration of such an hypothesis.

For practical reasons, because of the nature of existing data on the thermal aspects of child development and the school, such an hypothesis is best constructed in three parts.

1. The incompleteness of growth and development of the school child, and the mass-skin area ratio of that child as compared to the adult, necessitate a different set of standards for controlling the thermal environment of the school child than those used for controlling the work environment of the adult.

Kugelmass best summed up the metabolic needs of the school child when he said: "The child needs food for growth, maintenance and repair of his body . . . . Each of these processes take place simultaneously . . . . Protoplasm is self-perpetuating, capable of amassing living substance at the expense of non-living matter which serves as food; it is self-regulating, capable of utilizing indespensible nutrients for maintenance; it is self reparative, capable of replacing, through the agency of food, the structural increments degraded by metabolic processes. These chemical changes involve the liberation of potential energy of foodstuffs in the form of mechanical work, heat, or electricity; and the disintegration of complex compounds into simple substances which cannot be used further by protoplasm and are therefore excreted. Thus does the stream of matter into protoplasm continue to produce growth if synthetic processes in the cells remain in excess of energy-yielding reactions and to maintain life if constructive processes are counterbalanced by destructive."

The child's readiness to learn and to perform at any level of his education, and his ultimate degree of maturity and performance efficiency is dependent upon maintaining his growth rate at an optimum. This is well borne out by the researches in child development of Gesell, Olson, and many others. This aspect of the child's development is critical at all age levels to maturity.

What must be recognized by the designers of the thermal environment of the child, is that the human organism has no special mechanism to assure that the metabolic needs of growth will be met. Activity demands for nutrients always take precedence over growth demands in the child. In other words growth is only possible when both basal and activity requirements have been fulfilled.

The average daily caloric requirements to meet growth needs during the ages of 6 to 16 years is 10-15 calories per kilogram of body weight. Growth function is a storage function and no heat is produced in this process. The encroachment on this function by anabolic demands due to stress or excessive action induced by environmental factors, can do nothing but handicap ultimate successful learning and the final complete and mature functioning of the organism--which also are dependent upon the same processes of anabolism.

Two other factors of growth are worthy of recognition. Oxygen consumption in the child is increased during periods of rapid growth. These periods are both age-related and seasonal. Growth is greatest during the sixth year and between the twelfth and sixteenth years of the child's life. In addition, basal metabolic rate of all children is maximal between November and January due to this period also being the period of greatest increase in height and least gain in weight during the year. This increase in oxygen consumption during growth spurts necessitates a more careful control of the thermal environment of the child so as to protect growth, than is needed for the control of the environment of the adult in whom growth has already been attained.

The second factor is that, in the developing child, and especially the young child, incomplete nervous structure means muscle tone is poor so loss of body heat is not well-regulated without adequate protection by careful control of the thermal environment.

In young children the mechanism for controlling the loss of heat is poorly developed and hence their body temperature is more likely to undergo variations. While in an adult muscular work affects the body temperature but little, a child may develop a fever by a fit of crying. Young children, should, therefore, be more closely guarded against too rapid loss of heat.

Basal metabolism is more closely related to surface area than to height and weight. Under basal conditions energy is continually produced to maintain the normal body temperature by compensating for the loss of heat from the surface of the body. The rate of heat production is greater in children than in adults because the child's body surface is proportionately greater (among other reasons). For examples, the basal heat of the adult is 20 calories per square meter of skin surface per hour. In children the heat is as follows:

Age	Boys (cal./sq.meter/hr.)	Girls (cal./sq.meter/hr.)
7 years	47.5	46.5
13 years	41.9	34.7

The heat production per minute of the average resting child in a fasting state is about 1.22 calories.

Well established research in children's nutrition shows the total daily caloric requirements of the school child of all ages, as compared to the adult, to average as follows:

Requirements per Kilogram of Body Weight

	School Child (Cal/kg)	Adult (Cal/kg)
Basal	35	25
Growth	10	0
Activity	25	10
Food Conversion	10	5
	80	40

The basal requirements given above include the 2.5-3% of the daily intake needed for tissue repair. This amount, together with the requirements for growth, include the non-activity and non-heat producing aspects of the child's daily intake. With the exception of the approximately 5% of the caloric intake which is converted into mechanical energy in activity in both the child and the adult, the remaining items of basal need, activity, and food conversion shown above for both children and adults represents the heat production of each per day.

The total daily caloric intake of the child in school is virtually the same as that of the adult engaged in a sedentary occupation. To illustrate: the average daily requirement of a man (150 lb.) per day, engaged in sedentary work, is 2,400 calories. The average daily needs of the school child is as follows:

Children's Total Daily Caloric Requirements

Age	Boys	Girls
7 yrs.	1,918	1,757
9 yrs.	2,287	1,932
11 yrs.	2,406	2,096
13 yrs.	2,522	2,381
15 yrs.	3,068	2,337

Very little additional evidence is needed to substantiate the first portion of our thesis that different standards are needed for controlling the thermal environment of the school child than those used for the adult.

(It is assumed the reader is familiar with the shifts in heat loss of the body through radiation, convection, and evaporation, that take place at different temperatures and under different conditions of air movement and humidity, so no elaboration of that data is presented here to show the applications of the above metabolic data to control needs and processes in the thermal environment of the child.)

2. Because the "child learns through activity" and that activity is physical even though covert in an apparently passive learning situation, and, because organic structure and function are modified through stress and action induced by any energy organization, the thermal environment of the school child requires more careful control in all of its aspects (temperature, air movement, and humidity) and more careful planning for programming these controls, than what is presently done if we would assure promotion of optimum learning and development.

Freeman's studies of the energetics of human behavior, McCullough's work in applying cybernetics to the human nervous system, Renshaw's work in visual dynamics, and the work of many other reputable investigators in the psycho-physical aspects of learning and behavior have all demonstrated that perception, learning, and other psychological phenomena are derived from motor actions, covert and overt. In other words there is a physical aspect--a heat producing aspect--in every part of the learning process as directed by the school. How significant this aspect is becomes apparent when we examine some existing data on caloric needs in the child while engaged in different activities. For example, the caloric consumption of the child--his heat production--increases 3% over basal needs while merely solving a mathematical problem. Emotional responses (which enter into the attitudinal aspects of learning) increase heat production 10% over basal production; and, just the motor activity of sitting at a desk increases basal heat production by 25 to 50%.

Other data on the heat production changes in psycho-motor function shows increased energy expenditure, over basal, in problem-solving situations changing metabolic rates by as much as 100-200% in talking or walking, and from 5 to 10 times in some types of severe activity.

Some of these changes for the child of school age are illustrated in the following table:

Activity	Requirements in Cal/hr/kg
Sleeping	0.93
Lying still	1.10
Sitting at rest	1.43
Reading aloud	1.50
Standing relaxed	1.50
Standing at attention	1.63
Light exercise	2.43
Walking slowly	2.86
Active exercise	4.14
Walking downstairs	5.20
Walking upstairs	15.80

Education's knowledge of the activity aspects in learning is bringing about a sweeping curricular modification over the "passive-absorption" methodology of the three R's of a generation ago. Instructional methods are becoming more informal and less "informational." The child finds things out for himself by "digging and doing" under the teacher's guidance. Classrooms are becoming workrooms, and disciplined inactivity is changing to varied directed activity throughout the day. Physical action follows listening or bookwork. Communication with other children, cooperative research, action, and construction is replacing individual passive study of books.

All these classroom and curricular changes mean that a rigid control of the thermal environment is needed to maintain optimum body temperature in the school child at all times, if we would have optimum learning and development. In addition, this control must alter as activity in the classroom alters, to assure optimum function throughout the school day, and optimum readiness to learn in subsequent school periods.

Data and opportunity for both these approaches to control is possible. Measurements of the metabolic shift in children, over basal activity, have been made in sufficient numbers, and exist in standard pediatric literature. Also, curricular programming is following closer and closer the basic diurnal metabolic cycle of children, which is also well established. What remains, is the conversion of these physiological data into engineering applications.

3. Full rapport in problem-solving situations (such as school tasks), is dependent upon shifts in internal body temperature and upon close maintenance of certain internal body temperature levels. This necessitates rigid control of all the thermal factors of the classroom to maintain these internal body temperature levels, within the varying rates of heat production in all the various activities of the child in order to assure optimum rapport with the learning task and optimum learning and developmental outcomes.

This part of our hypothesis is based on research so recent that, while the process has been identified, the norms have yet to be established.

Kleitman, University of Chicago Medical School, has demonstrated in his study of the sleep-wakefulness cycle that the maintained internal temperature is not a point (the classic 37° Centigrade or 98.6° Fahrenheit), but is a range, varying through a diurnal cycle. Others have verified this finding. These diurnal differences vary as much as a degree F. above and below the classic averages.

The uniqueness in Kleitman's research is his demonstration that problem-solving rapport goes up as the internal temperature goes up above the average, but within this range. The converse is also true. Rapport with the environment and the ability to solve problems also goes down as the internal temperature drops below the accepted averages. These changes of internal body temperature are mediated by a control mechanism inherent in the nervous structure of the organism, and by the stimulation of muscular action with its resultant increase in heat production.

In the writer's opinion the reason for these changes of rapport and problem-solving changes is probably the Q_{10} or changes of the velocity of chemical reaction within the motor system of the organism, due to the increases or decreases of body temperature. These controlled shifts of as little as a fraction of a degree under or over the average of internal temperature apparently alters this velocity sufficiently to bring the speed of reaction time up to a level at which the whole resources of the organism are integrated into an action pattern which makes for solving environmental stresses with least effort. Similar reductions in internal temperature apparently introduce inertias, due to a slowing of reaction time, that put the organism into a basal or resting state, thereby reducing or severing rapport with the external surround.

Excesses of internal body heat, over the optimum upper temperature level for problem-solving actions seem to trigger a control mechanism which reduces the organism's activity or integration, just as losses of internal heat below the optimum lower level for rest trigger motor action to increase the heat level.

With the wide variation in heat production of the child in various curricular activities, and the above need for maintaining internal temperature at a critical level in order to have optimum problem-solving capacity, the whole problem of control of the thermal environment must be approached, not as a matter of comfort (the basis of present standards), but as a matter of the needed retained heat for best learning.

Considerable more work must be done to establish the norms of these upper and lower temperature levels for children, together with their tolerances for variations while engaged in school activities. Sufficient information of temperature changes in various school activities now exist--as well as information on the limits within which these norms will probably fall--to necessitate that school controls be planned with all the aspects of the thermal environment in mind which could affect this temperature function in learning in all types of learning tasks. In addition, emphasis must be put on the need for complete, rather than partial controls of the thermal environment of classrooms, including programming of those controls, in order to assure that the child has command over all his capacities and resources while performing school tasks.

Partial Bibliography

Kugelmass, New Nutrition in Pediatric Practice, Lippincott, 1940

Best and Taylor, Physiological Basis of Medical Practice, Williams and Wilkins, 1945

Bull, Physical Biochemistry, Wiley, 1943

Freeman, The Energetics of Human Behavior, Cornell, 1948

Laurens, Physiological Effects of Radiant Energy, Reinhold, 1933

Handbook of Human Engineering Data, Second Edition, Tufts College, 1951

Gesell, Developmental Diagnosis, Hoeber, 1945

Abramson, Problems of Consciousness, Josiah Macey Jr. Foundation, 1950

McCullough, Machines that Think and Want, Brain and Behavior, A Symposium, University of California, 1950