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THE AGE VARIABLE IN PSYCHOLOGICAL RESEARCH[1]

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This paper examines the treatment of the age variable in the conception, design, and interpretation of developmental research. The dissatisfaction with the status of age as a concept and its use in research is attributed to the widespread tendency to consider age as an independent variable, comparable to others employed in differential research, and to study age *differences* rather than age *changes*. An alternative view is presented, which treats developmental questions as analogous to other phenomena involving changes in behavior over time. It is suggested that age be incorporated into the *dependent* variable in developmental studies, by defining the latter in terms of specified aspects or parameters of the function describing the changes which occur over age for a given behavioral variable. Implications of this view for developmental research are brought out, with particular reference to problems of description and quantitative analysis of developmental change, to the application of the experimental method in developmental research, and to the study of individual differences in the context of developmental change.

The chronological age of the individual has generally represented one of the most popular independent variables used in child development research and is included with some frequency even in research of a general experimental nature. Indeed, in spite of widespread dissatisfaction with research based on the Behavior = *f* (Age) paradigm, there seems little question that age, like sex, is here to stay. For the psychologist, age shares with sex the attraction of its great visibility as a dimension of individual variation in behavior, one which is not only readily measurable but accounts for a substantial portion of variance in a variety of behavioral measures.

Considering the popularity of this variable in psychological research, there has been a notable reluctance on the part of psychologists to examine the question of scientific method, inference, and theory which arise when differences in behavior are related to age. One important exception in this regard is to be found in Kessen's (1960) thoughtful discussion of the place of statements about developmental change in psychology and of the problems of control, research design, and interpretation which such statements create. Birren (1959) has contributed a similarly valuable discussion of the role of this variable in the study of aging. Yet neither of these authors has come to grips with the particular character of the age variable as a dimension along which temporal *changes* in behavior are charted, and the implications of this fact for questions of scientific interest and research design which arise in the use of this variable.

It is the intent of this paper to suggest a reformulation of the place which the age variable occupies in behavioral research, which should meet the major criticisms that have been advanced against it and thus assuage those who have felt uneasy in its use. Once the case for such a reformulation has been presented and argued, it will be applied to an examination of selected questions of design and methodology in developmental research, to indicate something of its scope and to bring out some of the ways in which its adoption would lead to a rethinking of such issues as the place of descriptive re-

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search in developmental psychology, the appropriate forms of quantitative analysis, the conception and design of experimental studies of developmental processes, and the place of individual differences in developmental research.[3]

Status of Age as a Variable

Dissatisfaction with research based on the paradigm, Behavior = *f* (Age), has typically been based on the purely descriptive character of such statements, and the failure of research conforming to it to isolate the particular variables which actually determine or mediate the variation of behavior with age (cf. Bijou & Baer, 1963; Kessen, 1960). For the same reason much of developmental theorizing, built on nonexperimental research of this type, has been regarded as suspect (Zigler, 1963). Age, it is asserted, is at best a shorthand for the set of variables acting over time, most typically identified with experiential events or conditions, which are in a direct functional relationship with observed developmental changes in behavior; at worst it is merely a cloak for our ignorance in this regard.

As one way out of this predicament, some psychologists, notably those of the Skinnerian persuasion, such as Bijou and Baer (1963) and Staats and Staats (1963), have tried to circumvent the use of age altogether and to attempt to program developmental changes directly by subjecting the individual to appropriate histories of reinforcement. However successful these attempts may have been, they necessarily have dealt with narrowly delimited responses, elicited under highly specific conditions of stimulus exposure, reinforcement schedules, etc. Few outside of the Skinnerian camp would argue that this represents a viable approach to developmental problems in general. For in many areas, notably in the domain of perceptual and cognitive development, uniform changes with age occur under much too diversified a set of conditions of experience to permit the isolation of any specific factors determining these changes.

If we probe more deeply into the reasons for the uneasiness which is generally felt in using age as a main variable in psychological research, and the Skinnerians' insistence on replacing it by specifying particular determinants of developmental change, we find that they can be traced to the assimilation of the study of age differences to the model of differential research. In the usual study involving the comparison of age groups, age does indeed seem to play the role of an independent variable analogous to that of such variables as sex, IQ, socioeconomic differences, etc., which the differential psychologist has traditionally employed. This analogy is, as shall be seen, a specious one, but it accounts for the fact that the objections most commonly raised against the use of age are those which experimentalists have leveled at the differential model of research generally, that is, at those studies in which differences in behavior are related to differences in the composition or characteristics of preselected samples—objections relating to the uncertainties of causal inference, of separating out the role of the presumed independent variable from others that may be operating, etc. (Cronbach, 1957).

Yet this way of looking at the role of the age variable ignores a critical point: when an investigator compares, for instance, a group of 6-year-old and a group of 10-year-old children, he is in fact interested in studying the *changes* in behavior occurring over this age period; that is, he assumes that the 6-year-olds would come to perform as did the 10-year-olds, if he had been patient enough to wait four years to retest them. This assumption is valid, of course, only to the extent that the two age groups can be considered equivalent in respects other than age, and in particular that there are no *cohort* differences between them, that is, differences in the populations of individuals born 6 as opposed to 10 years ago. Such cohort differences would constitute a true differential variable, and the importance of teasing out their possible role in developmental studies has been persuasively argued

[3] A more comprehensive treatment of questions of methodology in developmental research, from the perspective of the role of age presented in this paper, will be found in a companion paper prepared for a recent Conference on Life-Span Developmental Psychology (Wohlwill, 1970).

by some psychologists (Baltes, 1968; Schaie, 1965, 1967). Yet recognition of the potentially contaminating role of cohort differences in developmental studies only serves to bring out more sharply the difference between age as a dimension of intraindividual change and such other, purely differential variables.

In order to see more clearly the implications of this emphasis on the study of behavior change, let us compare the study of age differences with that of interspecies differences. Although ontogenetic and phylogenetic differences have on occasion been treated as analogous or closely similar, there is one major methodological difference between them. Unlike age changes, the evolutionary changes which underlie phylogenetic differences cannot be observed as they are occurring; nor can they be directly inferred from cross-sectional comparisons of the species currently in existence, since these are the product of the action of evolutionary forces which have been modifying the species within any given branch of the phylogenetic tree (cf. Simpson, 1958). It is only the developmental psychologist's inclination to opt for the cross-sectional shortcut rather than studying change directly, which has tended to obscure this important difference, and has allowed the study of developmental changes to become identified with differential types of problems.

Age as Part of the Dependent Variable in Studies of Developmental Change

Rather than treating age as an independent variable comparable to other dimensions of intraindividual variation, a very different way of conceptualizing it may be suggested, which accords to it a status equivalent to that which the time variable occupies in other fields, such as the experimental study of adaptation, learning and forgetting. Let us view age simply as a dimension along which the behavior changes which are the concern of the developmentalist are to be studied, that is, it is incorporated into the definition of the *dependent* variable of interest to him. Thus, to the extent that the investigator confines himself to charting such changes within a Behavior $= f$ (Age) paradigm, he is only *describing* a set of phenomena which are the subject of study for him. This is by no means to deprecate the role of such research—indeed, as will be argued presently, descriptive research of this kind, precisely because it deals with behavior change, occupies a far more important place than it does in other areas of behavioral investigation. Nevertheless it remains descriptive, and statements to the effect that behavior "is a function of age" are accordingly to be avoided, since they do not really involve functional relationships between a determining and a determined variable.

True functional relationships, for the developmental psychologist, would entail relating specified attributes of the age changes themselves to particular independent variables, whether experimentally manipulated by the investigator, or studied *in natura.* Thus, the interest might be in comparing motor development in normal and institutionalized infants, as in the work of Dennis (1960): Here the dependent variable could be defined as the age of onset of walking, or some other specified behavior which is typically subject to developmental change. Similarly, the *rate* of increase in vocabulary might be compared for twins as compared to singletons: The dependent variable would then be the rate of change in vocabulary size, or conceivably even the function describing this change in relation to age, considered in terms of specified parameters such as period of maximal growth, inflection points, asymptotal level, etc.

The first of the two examples just mentioned brings up a revealing point, namely, that in this, as in any developmental study, it is possible in principle to differentiate two individuals (or groups) either in terms of the difference in (mean) level of attainment on the behavioral dimension at a given age, or alternatively, in terms of the difference in the age at which some given level or type of behavior is attained. For instance, if we say that Individual A obtains a score X on an achievement test which exceeds Individual B's score Y by d units, an alternate way of expressing this difference is that A is accelerated relative to B, that is, it will take B some amount of time t to attain the same value X (assuming that A and B are in process of development with respect to the dimension in question).

This interchangeability between age and response magnitude on the dependent side itself represents a powerful argument for incorporating age into the definition of the dependent variable. It presupposes, however, that we are dealing with a dimension of behavior with respect to which any individual can be expected to exhibit consistent changes over the course of his development. Speaking more generally, the approach to the handling of age which is being proposed is applicable only to the extent that we are dealing with behavioral variables for which the general course of development (considered in terms of direction, form, sequence, etc.) remains invariant over a broad range of particular environmental conditions or circumstances, as well as genetic characteristics. Physical growth provides an obvious example: individuals grow taller, regardless of whether they are brought up on a diet of milk, cereal and beef, or rice and potato soup, provided they grow in a growth-sustaining environment, and possess the physiological equipment required for growth (e.g., a normally functioning pituitary gland).

Can we find similar cases in the realm of behavioral development? Most assuredly, notably in such areas as perceptual, cognitive, and linguistic development. Take, for instance, the growth of depth perception in the child, which develops apace, whether his environment is that of an urban slum or of the Kansas wheatfields, provided that he has exposure to some minimal amount of visual stimulation, and the visual apparatus and neural equipment necessary to transmit and make use of this sensory information (cf. Wohlwill, 1966, for a somewhat more extended presentation of this argument for the nonspecificity of experience). This does not mean that the particular environmental conditions may not influence the rate, terminal level, etc., of development for the variable in question; only that no specific one constitutes a *necessary* condition for the occurrence of the developmental changes. While this nonspecificity does not preclude the possibility that eventually prerequistes for development will be found of a much higher order of generality—equivalent to the role of vitamins in growth, or of patterned stimulation in perception—it makes it possible to enunciate broadly generalizable statements concerning the characteristic form of developmental changes for a given aspect of behavior, without reference to particular determining variables.

Given, then, a variable that is developmental, that is, for which changes with age are found which are uniform and consistent across a wide range of individuals and environmental conditions, in the sense just mentioned, it becomes profitable to approach the study of age changes in the manner which has been outlined above. More specifically, we can define the task of the developmental psychologist as one of describing these changes, of determining the structural relationships and temporal patterning of changes among sets of such variables, and of specifying functional relationships between particular situational, experiential, or organismic variables and selected parameters or attributes of these changes.

What behavioral variables qualify as developmental in this sense? Some have already been mentioned in the illustrations given, for example, speech and motor development, or space perception. Others could be cited from the field of the development of perceptual and cognitive skills, possibly curiosity and related variables, and perhaps even certain aspects of social perception and interaction, and emotional development. Variables, on the other hand, which show consistent age changes *only* for individuals subjected to specific experiences, such as swimming skill, reading or writing ability, or other responses acquired through directed teaching, differential reinforcement, or exercise would not qualify as developmental; neither would those which represent dimensions of emergent individual differences rather than of directional developmental change, such as aggressiveness, attention seeking, and the like.[4]

[4] This distinction appears so similar to that which McGraw (1946) proposed between "phylogenetic" and "ontogenetic" behaviors, that a clarification is in order, lest this discussion become

Time as a Dimension for the Study of Psychological Processes

The proposed treatment of the age variable would relate the study of development, that is, of age-related differences in behavior, to a variety of other phenomena of interest to psychologists which similarly involve systematic changes in behavior over time. Let us refer to just one such area: the study of perceptual adaptation. Here, too, we find time used as a dimension along which the changes in behavior of interest are charted in an essentially neutral sense, that is, without investing any causal significance in the time variable itself. Nor do we find adaptation researchers necessarily turning to other, directly manipulable variables for which time could be said to represent a mere shorthand.

For instance, in the area of dark-adaptation (cf. Bartley, 1951), research at the behavioral level has consisted of the description of the prototypical temporal function and the comparison of the slope and form of this function under different conditions of specified independent variables, such as the size and location of the retinal field, the intensity of the preceding illumination, etc. These variables can be placed into a functional relationship with the differences in the parameters of the dark-adaptation curve; they do not explain, nor were they intended to explain, the changes in response which take place over time.

If we ask what form the explanations for these changes actually take, the answer is well known in this case: we turn to an account at the level of physiological mechanisms, more specifically the cycle of breakdown and regeneration of rhodopsin. But note that such reductionist explanation does not dispense with the time dimension, which is still essential to the description of these physiological processes.

falsely assimilated to the maturation-learning question. The present developmental dimensions are not conceived to be independent of environmental influences, as McGraw's phyletic skills are; only the occurrence of change—as opposed, for example, to the rate of such change, its terminal level, etc.—are considered to be independent of specific environmental conditions. Furthermore, a much broader range of behavioral variables is encompassed in the present term than in McGraw's concepts, which referred exclusively to motor development.

As yet, however, most response changes over time are not reducible to lower level physiological mechanisms, and in many cases no psychological mechanisms short-circuiting the time dimension can be invoked to account adequately for the changes. Cases in point would include perceptual adaptation of the "normalization" variety, as studied by Gibson (1933), and, indeed, many of the phenomena of prism adaptation recently studied. Here, to be sure, we find at least one psychological theory attempting to explain adaptation in terms of a single psychological process defined without reference to time, that is, reafferent feedback (Held & Freedman, 1963). Yet the accumulating evidence indicates that while such feedback may be a powerful determinant of amount or rate of adaptation, it is not a necessary condition for its occurrence (cf. Rock, 1966). It is of interest to note further that the prism-adaptation literature suffers from some of the same limitations as the developmental literature, in that a process assumed to be occurring over time is frequently indexed by a single quantity, the *amount* of adaptation after a certain period (usually measured indirectly, through extent of aftereffects). This has meant that the course of change of perception during the adaptation period and the parameters of the adaptation function have been neglected, to the detriment of an adequate picture of the adaptation process (e.g., Devoe, 1969; Hay & Pick, 1966).

In sum, change in response over time represents a central characteristic of diverse aspects of behavior; accordingly, in the description and functional analysis of phenomena involving such change, the time dimension is indispensable, to the extent that it is not reducible to a set of specifiable external events determining the change. The central thesis of this paper is that in the study of a variety of changes in behavior which occur during the course of the individual's development from neonate to mature adult (and possibly even beyond), age is profitably treated in these terms, that is, as a dimension essential to the investigation of the phenomena of developmental change.

IMPLICATIONS OF THE PROPOSED REFORMULATION OF THE STATUS OF AGE

Acceptance of the preceding argument concerning the treatment of the age variable carries with it a number of interesting implications for the conduct of research on problems of development, with particular regard to questions of methodology, design, and scientific inference. Let us focus on five of these in particular. They concern (*a*) the place of descriptive research, (*b*) the construction of viable developmental dimensions, (*c*) the approach to problems of quantitative analysis, (*d*) the meaning of the experimental method, and (*e*) the handling of individual differences.

The Place of Descriptive Research in Developmental Psychology

Any set of empirical data which falls into the Behavior = *f* (Age) paradigm represents a description—typically partial—of a developmental function for a particular response. This is true regardless of the intent of an investigator to invest such data with theoretical significance for the verification or rejection of a theoretical hypothesis. Data of this type vary widely, however, in the information which can be conveyed in the description of the developmental change in question. They range from the mere finding that age represents a significant source of variance, or that there are significant differences in the incidence of given types of responses associated with age at one extreme, to a precise determination of the mathematical form of the relationship between the behavioral variable and age, with the values of the constants calculated to the *n*th decimal place, at the other.

In considering the place to be accorded to descriptive data of this kind, it will help to return to the earlier example of the study of dark adaptation. There would be little interest in a finding that absolute thresholds obtained after varying intervals of time following exposure to light differed significantly. Contrast this with the compelling character of the dark-adaptation curve when plotted in detail, for even a single observer, so as to exhibit the two branches of the curve. This information, while not pointing to any specific basis for adaptation, immediately presents a major finding, suggestive of a dual-process phenomenon, which an adequate account of dark adaptation needs to be able to handle.

This illustration suggests why accurate, systematic description has played such an important role in the developmental sciences —indeed, in any science dealing with systems undergoing change or motion (e.g., astronomy). The reason goes beyond the truism that it is essential to have an adequate knowledge of a phenomenon before one can set about explaining it. More to the point, the observation of such a system, precisely because it exhibits change, and thus produces variation that is measurable as it occurs over time, can provide more direct clues to the nature of the processes or mechanisms governing it than is possible in a purely static system or object. Thus in a developmental science, observation and experimentation are apt to be used in a close, coordinate interrelationship, and frequently the line between description and explanation becomes blurred.

These points are convincingly illustrated in the work on mathematical growth curves for the study of physical growth. This work runs the gamut from a purely empirical, curve-fitting approach, as favored by Sholl (1954), Waddington (1950), and others, to the derivation of growth curves from a priori mathematical models of the biological growth process (e.g., Bertalanffy, 1960; cf. also Shock, 1951). In spite of these differences in approach, all of this work is not only marked by an unselfconscious use of age as an irreducible parameter in the study of development, but relies on essentially descriptive data to provide a clear, economic specification of the essential characteristics of growth, and of differences in patterns of growth among individuals or groups. Just as in the case of dark adaptation, furthermore, such concise description of the course and characteristics of age changes has led directly to insights into the factors controlling or regulating growth, as in the study of adolescence (Tanner, 1962), and the work on effects of temporary illness on the course of growth (Tanner, 1963) to be discussed subsequently.

For a number of reasons, some obvious, others less so, we have seen little such mathematical treatment in the study of behavioral development thus far, with the notable exception of the study of the development of intelligence (e.g., Bayley, 1956; Thurstone & Ackerson, 1929). In view of the problems of scaling which arise with respect to intelligence-test data, the meaning and value of such attempts in this particular area is uncertain; however, even less precise and mathematically sophisticated modes of growth-curve analysis, such as the purely graphic approach applied to advantage by Riegel (1966) in his treatment of differential effects of aging on diverse performance variables involving linguistic habits (e.g., reading versus writing), can help us to obtain a clearer picture of the course of development along behavioral dimensions, and accordingly of the processes governing such development.

The benefits to be derived from the study of age changes at a descriptive level are not confined to the realm of quantitative changes. Questions of at least equal interest and significance arise with respect to qualitative changes, for which the analysis of developmental functions take the form of determining developmental sequences, so as to reveal the patterning of successively appearing behaviors. We need only think of the observational studies of motor development by McGraw (1943), Shirley (1931), and Gesell and his associates (cf. Gesell, 1954), or of the painstaking observations of Piaget (1952, 1954) on the development of sensorimotor schemata in infancy to appreciate the place of systematic descriptive work on the sequential appearance of behaviors in development. Piaget's sequences, to be sure, are embedded in an intricate theoretical superstructure, functioning much as a mathematical model may do in the study of growth or learning curves, the observations serving mainly to confirm the adequacy of the model, rather than to test specific hypotheses in a deductive sense. The work on the motor sequences, on the other hand, occupies a place more nearly corresponding to the empirical curve-fitting approach in the study of quantitative changes. Yet both types of research contribute importantly, and perhaps equally, to the specification of developmental process and even mechanism (cf. the laws of development formulated by Gesell, 1954, or the interpretation based on neuromuscular mechanisms which McGraw, 1946, has evolved to handle her findings of motor sequences).

There is one major difference between the qualitative and quantitative analyses of changes: In the case of the former, age ceases itself to be of importance as a continuum to which the behavioral changes are related, except for purely normative purposes; its essential role is to provide an independent criterion for ordering the responses developmentally. The main datum of interest in this type of study accordingly is the sequence of behaviors itself and the extent of its invariance across individuals. Age, or time, may nevertheless enter subsequently as a dependent variable in studying differential rates of development as a function of some condition or subject variable. For instance, the age at which a particular step in the sequence appears, or the time taken to move from Step A to Step B can be used as a measure of developmental rate.

Construction of Developmental Dimensions

A major difficulty to be faced in carrying out the analysis of developmental functions advocated in this paper is the considerable degree of dependence of behavioral measures on specifics of stimuli, situational conditions, instructions, and the like. This problem poses a challenge to developmental psychologists—that of finding measures of behaviors which distill information concerning age-related changes from the "noise" (for the developmentalist) of response variance attributable to stimuli, task conditions, etc. This is by no means as hopeless an undertaking as it may seem. For instance, in the area of the perceptual constancies, the overall picture of the developmental changes that occur is a fairly consistent one across different studies, employing different stimuli, background conditions, and even psychophysical methods (cf. Wohlwill, 1963). This suggests that a reasonably "robust" developmental dimension can be obtained by the use of a composite measure, derived from the responses to a set of situations representative of those used in the literature.

On the other hand, where a particular variable shows a potent interaction with age—as the distance variable appears to in the constancy literature, or the complexity variable in the curiosity area—we may redefine our developmental dimension so as to incorporate this interaction. That is, rather than defining constancy in terms of amount of error at a particular distance, we can (and indeed should) define it as the extent of the regression of perceived size with distance. Similarly, in the case of curiosity, the measure used could be an index of the slope, or possibly the curvature of the function relating the response to the complexity dimension.

Speaking in a more general vein, reliance on individual measures of a variable, chosen on the basis of a restricted operational definition, leads to situation-bound measures of behavior, which are better suited to the needs of the experimentalist for detecting effects of specific conditions manipulated by him than they are to the study of developmental change. It is undoubtedly no accident that the greatest strides in the study of psychological growth have been made in the field of intelligence and related dimensions taken from the study of individual differences, which are defined in terms of a broad set of behaviors rather than isolated responses. This is not to deny the value of concise definition of behavioral dimension, nor the desirability of extending research on developmental problems to some of the variables which have been intensively studied in the laboratory of the experimentalist. But in so doing, the developmentalist will have to pay much more attention to the problems of construct validity and dimensional homogeneity (as well as reliability) than the experimentalist has been wont to do. The details of these aspects of the construction of dimensions, and the problems involved in arriving at scales for developmental assessment applicable over a large segment of the age variable, are, however, beyond the scope of this paper.

Problems of Measurement and Quantitative Analysis

Let us suppose that we have obtained measures of some adequately scaled and dimensionalized variable over a reasonably extended segment of the age continuum, for example, at five age levels between the ages of 6 and 19. The typical procedure for handling such data is to carry out an ordinary analysis of variance, which may yield a finding of a significant "effect" of age, that is, the age variable represents a significant source of variance. (Negative findings in this regard are rare, since they are not apt to be reported in print.) But is this the most adequate procedure to follow in this instance? Once we depart from the conception of age as a differential variable, and eschew interest in differences among age groups *qua* groups, aiming rather at detailed description of the age function as the first task to be tackled, a more valid approach consists in obtaining a good first approximation to the *form* of a function by means of a trend analysis.

In this connection, we may refer to Grant's (1962) argument against a hypothesis-testing approach in situations involving the testing of a model, in which the intent is not to show the influence of a particular variable, by rejecting a no-difference hypothesis, but rather to fit a set of empirical data to some theoretically derived function. Accordingly, Grant makes a plea for shifting from a hypothesis-testing strategy in such cases to a parameter-estimation strategy. The situation appears similar in our case, even if we do not start from an a priori model specifying the developmental function. A trend analysis can be construed, in effect, as a curve-fitting enterprise, where the intent is to determine, as a purely empirical fact, the general form underlying the observed function or, in our case, the variation in response with age. Obviously, the procedure covers the special case in which there may be no consistent variation with age: in this instance, neither the linear nor any higher order components would prove significant. But the main point concerns the information to be derived from the data: we are generally not interested in rejecting the null-hypothesis of no age-related difference, but wish rather to determine the most likely form of the age function.

Apart from the specification of the form of the developmental function, through trend analysis or possibly more sophisticated curve-fitting methods, the stance taken here toward the study of age changes entails a more intensive concern with the measurement of change, and methods for determining correlates of change and interrelationships among measures of change for different variables. It is clearly not possible to go into detail on these matters here (cf. the symposium on the measurement of change, Harris, 1963; also Cattell, 1963, 1966). Suffice it to call attention to the desirability of obtaining longitudinal data, in order to assess change on a per-individual basis, and to raise one further point. When dealing with the study of change, correlational approaches take on an added dimension, as it were: the teasing out of relationships among variables in process of development differs from the study of correlation at a single point in time, or even over a randomly chosen set of occasions, as in Cattell's P technique. This is true both in terms of the place of this type of correlational analysis as a tool for scientific inference, and in terms of the analytic techniques it requires. For the aim here is to determine functional relationships between changes in behavior presumed to develop in interdependence with one another.

To give a very simple example, if two behavioral variables developed in unison (Figure 1a), or in an identical pattern, possibly staggered in time (Figure 1b), the inference of a functional interdependence between them would be far more compelling than would the finding of even a substantial correlation between them at some given age level. But there are more complicated possibilities, where the evidence might be more difficult to evaluate, such as where development on some function X depends on, that is, literally awaits, the prior development to some level of another function, Y (e.g.,

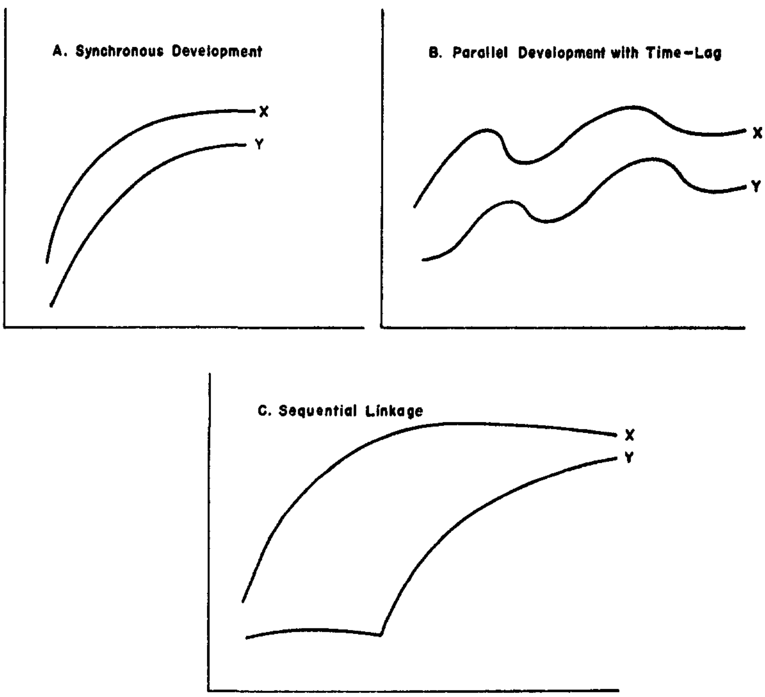

FIG. 1. Three patterns of interrelationships between variables undergoing development.

Figure 1c). The analogue of this case for the development of discrete, nonquantified responses has been frequently discussed in the past under the general topic of the sequential ordering of stages (cf. Flavell & Wohlwill, 1969). There is no reason to suppose that a similar pattern may not apply to continuous variables. But the question of the validity of drawing inferences as to functional interdependence remains a complex one in such cases, and the analytic tools available to study them, such as Campbell and Stanley's (1963) "cross-lagged correlation," are as yet very limited.

Meaning of the Experimental Method in the Study of Developmental Change

The determination of an age function does not qualify as an experiment. While few would disagree with this statement, it is important to be clear about the reasons behind this assertion. In the present view, it is not because age is an independent variable which is not subject to experimental manipulation, but rather because it is not an independent variable at all. The statement could be applied with equal force to studies determining the curve of adaptation for a single set of stimulus conditions, or for that matter to studies yielding a single learning curve. In these instances, time, or trials, are variables subject to experimental control; nevertheless, they do not function, in any real sense, as independent variables. (The very use of trials to criterion as a measure of learning should dispel any doubts on this score.)

An experimental study of development entails the manipulation of some particular factor or condition (or combinations thereof), in such a manner that its effects in altering the developmental function are revealed—in other words, it is this function itself which becomes the dependent variable. Relatively few instances of developmental research qualifying as experimental in this sense can be found. For it requires that the course of change on some behavioral dimension be traced over the total age period over which that variable is undergoing change, and that this be done for a control group and one or more experimental groups. Again the field of learning research provides an apt analogy: In studying the phenomenon of reminiscence, that is, of the effect of an interpolated rest period on speed of learning, we would generally not be satisfied with noting the difference between the experimental and control groups immediately following the rest period, but would want to obtain data on the total course of learning for each group (cf. Riley, 1953, 1954).

Most studies purporting to represent experimental studies of development fall short in one or another of these respects. Most typically, only a single measure of behavior is obtained, at the cessation of the duration of the experimental variable (see, for instance, the bulk of research on the effects of early experience in animals). The result is that there is no indication of the effect the variable has had on the course of the individual's development overall.

The absence of such a developmental focus, providing for follow-up testing of the behavior subsequent to the termination of the experience, is a notable shortcoming of much of the research on early experience, such as that carried out by Hebb and his associates at McGill University. Nor is the temporary as opposed to permanent character of the effects of early deprivation the only issue that we need to be concerned about. Another possibility to be considered is that an experience may have delayed effects, showing up only on behaviors which do not normally appear till some time after the termination of the experience. A case in point seems to be provided by the work of Harlow and his associates (Harlow, 1962; Seay, Alexander, & Harlow, 1964) on the effects of social isolation in infancy on later maternal and mating behavior.[5] We may also cite a study by Melzack (1954) on the effects of extended isolation experience in dogs. Upon initial testing (shortly after the end of the isolation period), the experimental animals were markedly impaired in

[5] Harlow's data are ambiguous in this respect, since the experience of the groups of monkeys compared seems to have differed in unspecified ways up to the time that they reached maturity (thus the delayed effect of the isolation in infancy is in doubt); furthermore, there may well have been undetected (or unreported) differences in their behavior *before* this time.

their ability to make adaptive avoidance responses to noxious stimuli. When retested a year later, these dogs did exhibit normal avoidance behavior; yet the control-group dogs continued to be differentiated from the experimental. They now displayed a new form of response toward the stimuli, namely aggression, which none of the isolated animals showed.

Such results, and others in which follow-up tests have been made to trace long-term effects of early experience, indicate that these effects can be properly understood only by considering them as superimposed on some assumed normal pattern of development, and assessing them by comparing the total developmental function under the normal and the special-experience conditions, that is, by letting the parameters of the developmental function serve as the dependent variable. Perhaps the most dramatic illustration of this point comes from the field of physical growth, where Tanner (1963) and his associates have made studies of the manner in which the mechanisms regulating growth (i.e., height) respond to temporary interruptions of the growth process occasioned by illness or malnutrition. As shown in the two cases illustrated in Figure 2, there is evidence for a period of

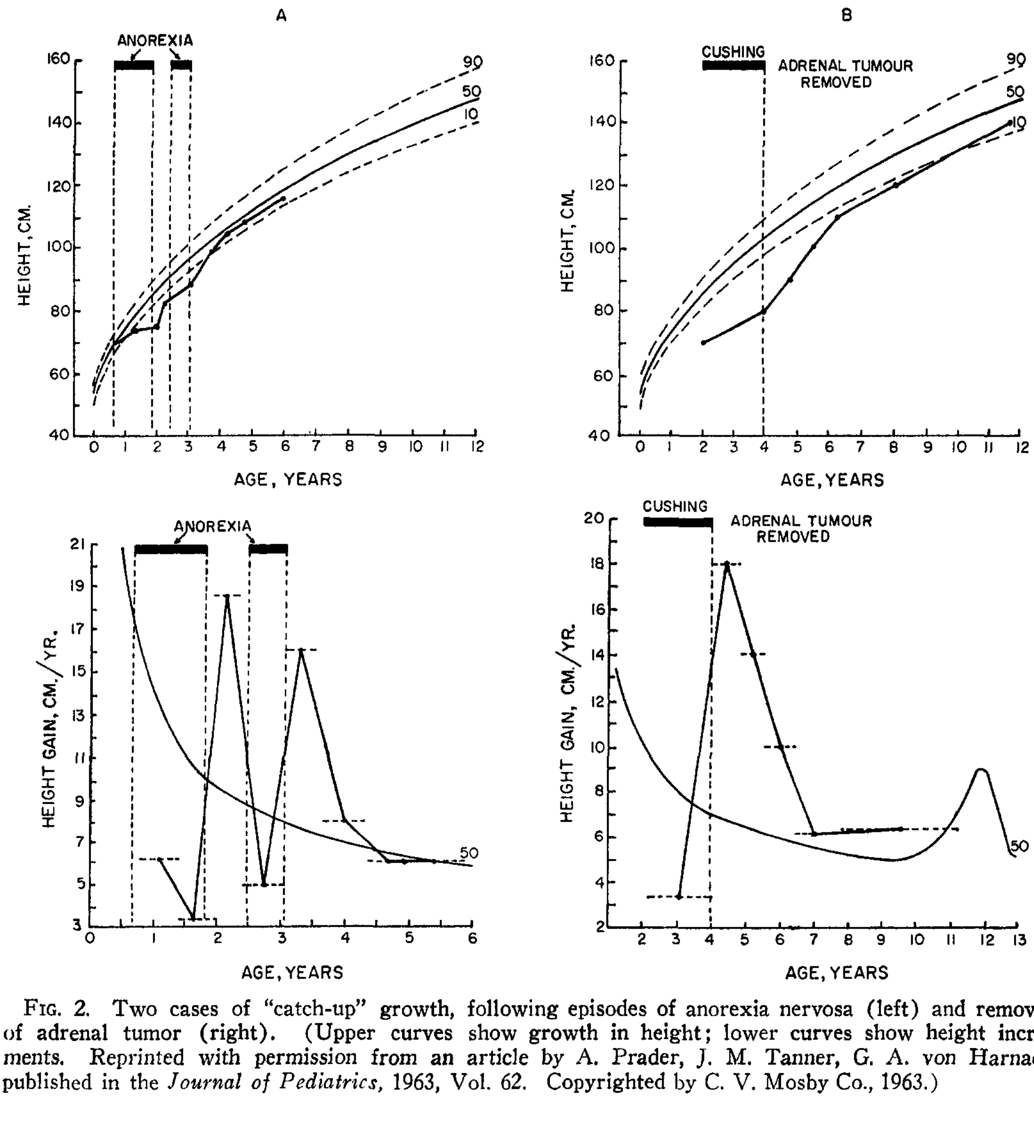

FIG. 2. Two cases of "catch-up" growth, following episodes of anorexia nervosa (left) and removal of adrenal tumor (right). (Upper curves show growth in height; lower curves show height increments. Reprinted with permission from an article by A. Prader, J. M. Tanner, G. A. von Harnack published in the *Journal of Pediatrics*, 1963, Vol. 62. Copyrighted by C. V. Mosby Co., 1963.)

accelerated growth ("catch-up" growth, as Tanner calls it), following the end of the growth-inhibition period, such that the individual attains the height he could have been expected to normally.

The point of this example is not necessarily to argue for the operation of such catch-up mechanisms in behavioral development; admittedly there is little research available that would bear on this issue. Rather, it is to point up both the importance of obtaining follow-up measures of the development of groups given deprivation or enrichment experience, as well as the complexities of design and interpretation introduced by so doing. In this connection we should note Campbell and Stanley's (1963) discussion of quasi-experimental designs; although intended primarily for the design of educational research in schools and similar field settings, it is directly applicable to the developmentalist studying the effects of some event or experience of limited duration on the course of development. Of particular relevance is Campbell and Stanley's "multiple-time series" design which entails measuring an experimental group repeatedly both before and after the experimental treatment, so that the effects of the latter can be gauged both directly, in terms of the shift in the function occurring after the treatment, and in comparison with the overall pattern of change over the same time period displayed by a control group.

To terminate this discussion on a more positive note, let us examine the implication in the proposed analysis of the role of experience on development for the definition of the variables to be controlled or manipulated in this type of experimentation. Thus, some of the parameters which King (1958) specifies in his discussion of the design of experiments on the effects of early experience, notably age at testing and the interval between end of the experience and the test, cease to represent isolable variables once the development of the behavior is monitored over the whole portion of the age continuum over which it is measurable. The only variables of real interest remaining—apart from the type of experience and the type of behavior chosen for study—are those of age at the onset of the experience and its duration. (Admittedly, controls are required to guard against cumulative effects of one test on subsequent ones.)

Interpretation of Individual Differences in Developmental Research

Developmental theorists such as Piaget and Werner and researchers studying age differences generally have not been noted for paying systematic attention to individual differences in behavior. Conversely, differential psychologists have rarely attempted to integrate developmental changes into their work or their thinking. Exceptions to this statement could be cited: the work of Witkin and his associates (Witkin, Dyk, Faterson, Goodenough, & Karp, 1962) and, from the factor-analytic side, that of Cattell (1963, 1966), has treated questions of patterning of individual differences as a function of age, as has the body of research inspired by the differentiation hypothesis of the development of intelligence (cf. Gullford, 1967, pp. 418ff.). Tucker (1963) has, furthermore, provided a model for the handling of developmental and differential data, involving an extension of factor analysis into a three-dimensional space. Yet, with the notable exception of Emmerich's (1964, 1966) work on changes in personality structure in the preschool years, little real integration has been achieved between the focus on individual differences and on developmental changes. Emmerich (1968) has, in fact, made a sharp differentiation between what he terms the "classical developmental view," tracing changes with age, and the differential approach, which to the extent that it has dealt with questions of development, has been mainly concerned with the problem of *stability,* that is, *constancy* of individual differences across age levels.

The present reformulation of the role of the age variable suggests ways in which interindividual variation in development can be treated under both of these two approaches. First of all, at the simplest level, individuals can be differentiated in terms of the characteristics of their developmental function, instead of their standing on a given behavioral dimension at a given age. This is, in effect, what has been done in the field of physical growth at a descriptive level, in specifying channels of development, as in the Wetzel grid (Wetzel, 1947). Individual differences are thus represented as variations around some assumed prototype function, and in the ideal case can be specified in terms of the values of the constants of that function.

If this might be described as incorporating a differential dimension into the classical developmental view, as Emmerich has stated it, the converse task—that of bringing a developmental dimension into the differential approach—is a more difficult one. It would consist in tracing individual differences as they emerge during development, either with respect to nondevelopmental variables, or with respect to standardized or otherwise relativized measures of behavior. While this has been achieved at the level of cross-sectional comparisons of factorial structure, the emphasis has been largely on the specification of the factors within a group, that is, of the dimensions along which characteristics of this factor space. A good illustration is provided by the research of Emmerich (1964, 1966), in which longitudinal data have been used to good advantage to separate out different types of changes in factorial patterns, some pointing to continuity, that is, constancy of the factorial definition of a given dimension, while others suggested transformations in the dimensions themselves.

Once the presence of factorially invariant individual-difference dimensions has been established over a certain age range, we can proceed to apply the rationale of developmental-function analysis in order to differentiate among individual children in terms of the pattern of change characterizing the development of the trait or attribute. More specifically, we may look at age functions for any given individual, specifying his standing on that dimension at different points in time, either in terms of standard-score measures, or possibly by recourse to factor scores on factors which have been demonstrated to be invariant over age.

One area in which analyses of this type have in fact been made is in the study of individual children's patterns of mental growth, based on patterns of changes in IQ scores. Using the longitudinal records of the Fels Research Institute study, Sontag, Baker, and Nelson (1958) have succeeded, through this kind of approach, in relating patterns in the development of intelligence to personality formation, specific events in the child's life, etc. It should prove equally feasible, as well as profitable, to undertake such analyses with respect to more purely differential dimensions such as aggressiveness or masculinity-femininity. For instance, the functional meaning of a girl's standing in late adolescence near the feminine end of the masculinity-femininity scale might be quite different, depending on whether she had consistently been highly feminine since early childhood, as opposed to going through a pattern of increasing masculinity (i.e., tomboyishness) over the course of her childhood, with a reversal at the onset of adolescence. Data from longitudinal studies such as Kagan and Moss's (1962) lend themselves ideally to this purpose, although the authors' predominant concern with the problem of the stability of traits apparently kept them from undertaking any such individual analyses.

Finally, let us bring into focus the complementarity between the two ways of looking at the development of individual differences discussed in this section, one based on differences in the form or pattern of a prototype developmental function, considered in absolute terms, the other on differences in the pattern of change (or lack of it) in a child's standing on a differential dimension, relative to his age group. For dimensions for which individual differences are superimposed on major developmental changes in absolute standing, the two approaches are in fact formally equivalent, and the information obtained from the second is in direct correspondence with that obtained from the first. The case of the development of intelligence illustrates this situation, the difference being equivalent simply to a shift from the use of mental age to that of IQ (cf. Figure 3 for an illustration of this point). There is, nevertheless, an important conceptual difference between them, insofar as one couches individual differences in such developmental

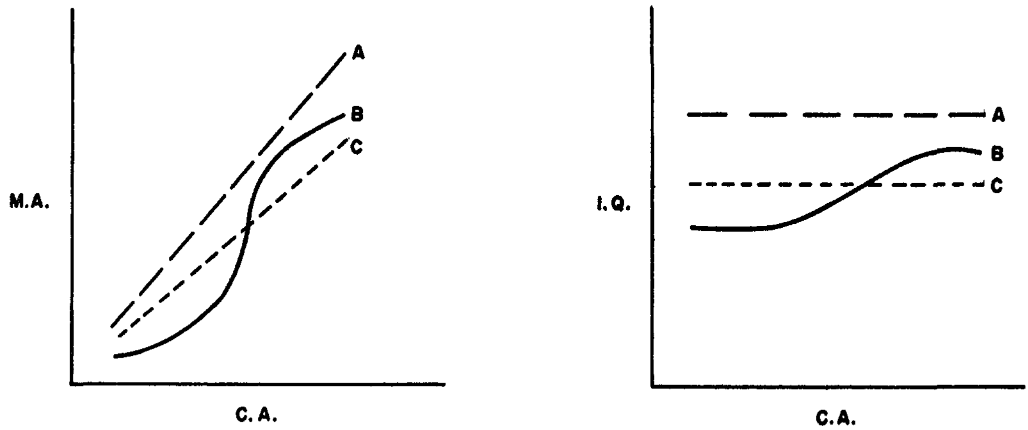

FIG. 3. Individual differences in intelligence development, pictured in terms of mental age (MA) (left) and IQ (right). (A, B, and C represent three individuals, developing at different rates—A: above average; B: well below average initially, accelerating subsequently to attain average terminal level, and C: below average.)

terms as retardation or acceleration, while the other will make reference to such expressions as normal or average, high and low, etc. (The difference is well caught in the distinction between mental retardation and mental deficiency.) This suggests further that the first approach is more appropriate for variables such as intelligence and vocabulary for which there are, indeed, major changes in level taking place with age, while the second will be more appropriate for true individual-difference scales which are basically orthogonal to the developmental dimension—notably bipolar scales in the field of personality, for variables such as aggressiveness, masculinity-femininity, etc.

CONCLUSION

Two points remain to be made in conclusion, one concerning the limitations on the types of analyses involving the age variable suggested in this paper, the other concerning the cost involved in applying them. First, the use of the age dimension in the manner advocated here makes sense only provided two criteria are met: (*a*) that substantial, reasonably situationally independent age changes occur with respect to the given behavior and (*b*) that the changes are not readily handled in terms of highly specific experience in the sense of the individual's reinforcement history, of practice or learning experience with a given task, or of particular events impinging on him. The rationale behind these criteria and the types of variables which may or may not conform to them have already been noted.

The second and final point to be made is that this approach places a fairly heavy burden on the developmental psychologist. First of all, it demands a mastery of requisite analytic techniques going beyond the standard armamentarium of inferential statistics acquired in the typical graduate training program. Second, it presupposes a willingness to transcend the traditional mold into which behavioral scientists are typically cast, as either experimentalists or differentialists; what is demanded, first of all, is a tolerance for and understanding of the place of painstaking descriptive analysis of behavior change, with nary a significant F or t at the end of the rainbow, and, beyond this, an ability to alternate between and effectively integrate the roles of the differentialist and experimentalist which are generally separated by a wide (and widening) gulf (cf. Cronbach, 1957). Third, and most critically, it is predicated to a considerable extent on the investigator's willingness and ability to collect longitudinal data, frequently spanning a considerable period of time. While there are certain aspects of behavioral development which may be adequately studied over a period of only two or three years (as in the case of the acquisition of Piagetian concepts, or certain aspects of language acquisition), it is typically necessary to cover a substantial segment of the period between birth and maturity. Shortcuts are sometimes possible, by combining longitudinal and cross-sectional approaches, but in general those intent on quick results, or immediate gratification, might be better advised to stay clear of developmental-analytic research of the type discussed here—or possibly to apply it to the study of faster-maturing species such as Drosophila.

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