# Age Changes and Age Differences[1]

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## Abstract

The concepts of age change and age difference are differentiated by introducing a three-dimensional model for the study of developmental change involving the notions of differences in maturational level (age), differences among generations (cohorts), and differential environmental impact (time of measurement). It is shown that age differences as measured by cross-sectional methods confound age and cohort differences while age changes as measured by the longitudinal method confounds age and time of measurement differences. Conceptual unconfounding permits specification of alternate models for the prediction of age changes from age differences and resolution of the meaning of discrepancies in the findings yielded by cross-sectional and longitudinal studies. Examples of alternative models for aging phenomena are provided.

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Almost as soon as objective measures were defined which could be used to index intellectual abilities and other cognitive functions, researchers began to express interest in individual differences on such measures. One of the most persistent of such interests has been the investigation of developmental changes in cognitive behavior. Most treatments covering age changes in cognitive behavior have closely followed the prevelant approaches in the description of developmental theories. Great attention has always been paid to early development, maturation during childhood and adolescence is fully described but then very little is said about the further development of intelligence and other cognitive variables during adulthood or senescence. In fact, the concern with age changes in cognitive behavior during adulthood did not come to be of serious interest to psychologists until it became clear that the I.Q. concept used in age scales was inapplicable for the measurement of intelligence in adults. As a consequence of the work of Wechsler (1944) in developing special measures for the description of intelligence of adults but also due to the earlier descriptive works of Jones and Conrad (1933) with the Army Alpha and that of the Stanford group working with Miles (1933) it soon became clear that somewhat different conceptual models would be required for the proper understanding of adult cognitive development.

It will be noted that we have emphasized the term age changes. The literature on psychological studies of aging has long been haunted by a grand confusion between the terms "age change" and "age difference". This confusion has beclouded the results of studies involving age as a principal variable and has loaded the test book literature with contradictory findings and what will be shown to be spurious age gradients. It is our intent to use this presentation to clarify in detail the relationship between age changes and age differences and to show why past methodologies for the study of age related changes have been inadequate.

Much of the literature on aging and cognitive behavior has been concerned with describing how older individuals differ from their younger peers at a given point in time. Such a descriptive attempt is quite worthwhile and is necessary in the standardization of measurements. This approach, however, is restricted to a description of the very real differences between organisms of various lengths of life experience at a given point in time. Unless some very strong assumptions are made, these attempts beg the issue and fail to produce relevant experiments on the question of how the behavior of the organism changes over age. This is a strong statement and it is not made rashly since it clearly questions much of the work in the current literature. But it is required since we find ourselves increasingly puzzled about the results of our own and others studies of age differences. Let us be explicit in clarifying the basis of our concerns and in tracing the resulting implications for the interpretation of much of the data in the developmental literature.

A general model has been developed which shows how the previously used methods of developmental analysis are simply special cases which require frequently untenable assumptions. This model has been described elsewhere in more detail (Schaie, 1965). At this time, however, it would be useful to state the most important characteristics of a general model required for the explanation of aging phenomena as they pertain to the relationship between age changes and age differences.

Let us begin then by clearly distinguishing between the concepts of age change and age difference. Before we can do so effectively, we must also introduce some new concepts and redefine various familiar concepts. The concept of "age" is, of course, central to our discussion. It needs to be carefully delineated, however, and whenever used will be taken to denote the age of the organism at the time of occurrence of whatever response is to be measured. Even more precisely, age will refer to the number of time units elapsed between the entrance into the environment (birth) of the organism and the point in time at which the response is recorded.

In addition it is necessary to introduce two concepts which are relatively unfamiliar in their relevance to developmental study. The first of these concepts is the term "cohort". This term has frequently been used in population and genetic researches and is rather useful for our purpose. The term implies the total population of organisms born at the same point or interval in time. Restrictions as to the nature of the population and the latitude in defining the interval in time designated as being common to a given cohort or generation must be determined by the special assumptions appropriate to any given investigation.

The second concept to be introduced is that of <u>time of measurement</u>. It will take on special significance for us as it denotes that state of the environment within which a given set of data were obtained. In any study of aging it is incumbent upon the investigator to take pains to index precisely the temporal point at which his measurements occur. Such concern is most pertinent since changes in the state of the environment may be contributory to the effects noted in an aging study.

With these definitions in mind let us now examine Figure 1 which will help us in understanding the distinction between age changes and age differences. Figure 1 contains a set of six independent random samples, three of which have a common age, three of which have been given some measure of cognitive behavior at the same point in time, and three of which have been drawn from the same cohort; i.e., whose date of birth is identical. If we compare the performance of samples 1, 2, and 3 we are concerned with age differences. Discrepancies in the mean scores obtained by the samples may be due to the difference in age for samples measured at the same point in time. But note, that an equally parsimonious interpretation would attribute such discrepancies to the differences in previous life experiences of the three different cohorts (generations) represented by these samples. If, on the other hand, comparisons were made between scores for samples 3, 5, and 6, we are concerned with age changes. Here the performance of the same cohort or generation is measured at three different points in time. Discrepancies between the mean scores for the three samples may represent age changes, or they may represent environmental treatment effects which are quite independent of the age of the organism under investigation. The two comparisons made represent, of course, examples of the traditional cross-sectional and longitudinal methods and illustrate the confounds resulting therefrom.

Lest it be thought that there is no way to separate the effects of cohort and time differences from that of aging, we shall now consider a further set of differences which may be called time lag. If we compare samples 1, 5 and 6, it may be noted that the resulting differences will be independent of the organism's age, but can be attributed either to differences among generations or to differences in environmental treatment effects or both.

Any definitive study of age changes or age differences must recognize the three components of maturational change, cohort differences and environmental effects as components of developmental change or, as in the past, we shall continue to confuse age changes with age differences and both with time lag. Hence, it may be argued that studies of age differences can bear upon the topic of age changes only in the special case where there are no differences in genetically or environmentally determined ability levels among generations and where there are no effects due to differential environmental impact. It follows, therefore, that findings of significant age differences will bear no necessary relationship to maturational deficit, nor does the absence of age differences guarantee that no maturational changes have indeed occurred.

As a further complication, it is now necessary to add the notion that differences in the direction of change for the confounded developmental components may lead to a suppression or exaggeration of actual age differences or changes. As an example, let us suppose that perceptual speed declines at the rate of one half sigma over a five-year interval. Let us suppose further that the average level of perceptual speed for successive five year cohorts declines by one half sigma also. Such decrement may perhaps be due to systematic changes in experience or due to some unexplained genetic drift. Whatever their cause, if these suppositions were true, then a cross-sectional study would find no age differences whatsoever because the maturational decrement would be completely concealed by the loss of ability due to some unfavorable changes in successive generations.

As another example, let us suppose that there is no maturational age decrement but that there is systematic improvement in the species. In such a case successive cohorts would do better than earlier ones, and cross-sectional studies would show spurious decrement curves, very much like those reported in the literature for many intelligence tests.

One of the most confusing facets of aging studies therefore is the fact that experimental data may reveal or fail to reveal a number of different combinations of underlying phenomena. Yet the understanding of the proper conceptual model which applies to a given set of data is essential before generalizations can be drawn. Let us illustrate the problem by considering some of the alternative models that might explain the behavior most typically represented in the literature on developmental change. Reference here is made to cross-sectional gradients such as those reported by Wechsler, (1944) or by Jones and Conrad (1933). These gradients typically record a steep increment in childhood with an adult plateau and steep decrement thereafter.

When we address ourselves to the question as to what developmental changes are represented by such data, we face relatively little difficulty in answering the question whether maturational changes are contained in the age differences noted during childhood and adolescence. Our own children provide us with at least anecdotal evidence of the longitudinal nature of such change. Whether this portion of the developmental curve, however, is a straight line or a positive asymptotic curve is still in doubt. Also, it should be remembered that even if we agree upon the validity of evidence for maturational changes, we must still consider that such changes will be over-estimated by cross-sectional data if there are positive cohort differences and/or negative environmental experience effects. Similarly maturational growth will be underestimated in the event of cohort decrement or the effect of positive environmental influences.

For the adult and old age portions of the developmental span matters are much more complicated. While we can readily accept the fact of psychological maturational growth during childhood, similar evidence of maturational decline on psychological variables by means of longitudinal study remain to be demonstrated. As a consequence, we must at least entertain also models which would account for age differences in the absence of maturational age changes.

The detailed analysis of the general developmental model (see Schaie & Strother, 1964) shows that it is possible to differentiate as many as seven hundred and twenty-nine models to account for developmental change if one considers the direction and slope as well as the three components involved in developmental change gradients. Of the many possible models, three will be considered now which seem to be high probability alternatives for the classical text book age gradients. Our three examples are models which not only would fit these text book gradients but would furthermore predict that the cross-sectional data depicted by the gradients could not possibly be replicated by longitudal studies.

The first of these models might be called an "improvement of the species" model. It holds that the form of the maturational gradient underlying the typical representatives of the text book gradients is positive asymptotic; i.e., that there is systematic increment in performance during childhood, slowing down during early adulthood, and that there is no further maturational change after maturity. The model further holds that the cohort gradient, or the differences between generations, should also be positive asymptotic. Successive generations are deemed to show improved performance for some unspecified genetic or prior experience reason, but it is also assumed that improvement has reached a plateau for recent generations. The effect of the environment is furthermore assumed to be constant or positive asymptotic also. When these components are combined it can be seen that they will provide a cross-sectional age gradient which shows steady increment during childhood, a plateau in midlife and accelerating decrement in old age. The same model, however, when applied to longitudinal data will predict steady increment during childhood, but slight improvement in midlife and no decrement thereafter. The only reason why the cross-sectional gradient will show decrement is due to the fact that the younger generations start out at a higher level of ability and thus in the cross-sectional study the older samples will show lower performance. Of course, this means no more than that the older samples started out at a lower level of ability even though they showed no decrement over their life span.

A second no less plausible alternative to account for the text book age gradients might be called the "environmental compensation" model. This model also specifies a concave maturational gradient with increment in youth and decrement in old age, much as the cross-sectional gradient. In addition, however, this alternative also calls for a positive environmental experience gradient. Here the effect of an environmental experience increases systematically due to a progressively more favorable environment. The effects of cohort differences in this model are assumed to be neutral or positive asymptotic. If the second model were correct, then our prediction of longitudinal age changes would result in a gradient with steep increment in childhood, but no decrement thereafter since maturational changes would be systematically compensated for by a favorable environment. Since the environmental component of change over time is not measured in the cross-sectional study, assessment would be made only of the maturational decrement which would give us information on the state of a population sample of different ages at a given point of time. But it would provide misleading information as to what is going to happen to the behavior of this population sample as time passes.

Thirdly, let us propose a more extreme alternative which we might label the "great society" model. This model specifies a positive asymptotic maturational gradient; i.e., increment during childhood and a plateau thereafter. The model further specifies a positive asymptotic cohort gradient; i.e., successively smaller increments in performance for successive generations. Finally the model specifies increasingly favorably environmental impact. The reason for calling this alternative the "great society" model should be readily apparent. The model implies (a) that maturity is an irreversible condition of the organism (b) that the rapid development of our people is reaching the plateau of a mature society and (c) any further advance would now be a function of continually enriching the environment for us all. Note that the cross-sectional study of groups of different age at this time in our history will still conform to the text book cross-sectional gradients. Their longitudinal replication, however, would result in a gradient which would be steep during childhood, which would level off during adulthood, but which would show continued growth until the demise of the organism.

Obviously, it is still possible that the straightforward decrement model might hold equally well for the classical gradients. The information we have on longitudinal studies such as those of Owens (1953) and Bailey and Oden (1955) and the more recent sequential studies by Schaie and Strother (1964a; 1964b) let it appear that any one of the above alternatives may be a more plausible one.

It is hoped that the examples just given have alerted the reader to some of the flaws in the traditional designs used for the studies of aging phenomena. Caution is in order at this time lest the premature conclusion be reached that increase in sophistication of our methods has indeed lead to a better understanding of how and why organisms age. Thus far it seems just as likely that all which has been investigated refers to differences among generations and thus in a changing society to differences which may be as transient as any phases of that society. Only when we have been successful in differentiating between age changes and age differences can we hope therefore that the provoking advances and methods in the more appropriate studies now in progress will truly assist us in understanding the nature of the aging process.

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Figure 1

Example of a Set of Samples Permitting all Comparisons Deducible from the General Developmental Model

| Time of Birth (Cohort) | 1955 | 1960 | 1965 |
|---|---|---|---|
| 1910 | Sample 3<br>Age 45<br>$A_1C_3T_1$ | Sample 5<br>Age 50<br>$A_2C_3T_2$ | Sample 6<br>Age 55<br>$A_3C_3T_3$ |
| 1905 | Sample 2<br>Age 50<br>$A_2C_2T_1$ | Sample 4<br>Age 55<br>$A_3C_2T_2$ | |
| 1900 | Sample 1<br>Age 55<br>$A_3C_1T_1$ | | |

Time of Testing

A - Age level at time of testing

C - Cohort level being examined

T - Number of test in series