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Source: *The American Journal of Psychology*, Vol. 67, No. 4 (Dec., 1954), pp. 573-589

Published by: University of Illinois Press

Stable URL: <http://www.jstor.org/stable/1418483>

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THE NATURE AND HISTORY OF EXPERIMENTAL CONTROL

By EDWIN G. BORING, Harvard University

Solomon has discussed the history of the concept of control in experimental work with especial regard to the use of control groups in the design of experiments,¹ finding no instance of the employment of a control group before the study of transfer by Thorndike and Woodworth in 1901² and no extensive use of control groups in experiments on transfer until Winch's study in 1908.³ It is easily shown that the concept of control is basic to all experimental design and is, indeed, inherent in the essential relational nature of a fact. The purpose of this note is to analyze the concept more fully and to say something more about the history of both the concept and the word.

The word *control* has three meanings: (1) a *check*, in the sense of a verification but thus also in the sense of a restraint, since verification restrains; (2) a *restraint*, in the sense of a checking and thus also in the sense of maintaining constancy; and (3) a *guide* or *directing*, in the sense of producing a precisely predetermined change, a constant and thus a restrained change. The word *check* itself has the first two meanings, though not the last, and the original meaning of *control* was *check*, for the word was *counter-roll* (*contre-rolle*), a duplicate register or account made to verify an official or first-made account and thus a check by a later roll upon the earlier. (Hence *controller*, which is misspelled *comptroller* because it has been thought of as meaning an accountant instead of a checker.) So the thought of correctness or conformity achieved by restraint runs all the way through the history of the word, even though what the psychologist hears nowadays about 'controlling behavior' suggests the promotion of action more than its restriction.⁴

* Accepted for publication September 10, 1953.

¹R. L. Solomon, An extension of control group design, *Psychol. Bull.*, 46, 1949, 137-150.

²E. L. Thorndike and R. S. Woodworth, The influence of improvement in one mental function upon the efficiency of other functions, *Psychol. Rev.*, 8, 1901, 247-261, 384-395, 553-564, esp. the eight-line paragraph on p. 558 where the use of a control group is described.

³W. H. Winch, The transfer of improvement of memory in school-children, *Brit. J. Psychol.*, 2, 1908, 284-293. The article antedates the development of the statistical method for dealing with group differences.

⁴Cf. B. F. Skinner, *Science and Human Behavior*, 1953, where the conception of control seems to me to be more positive than negative in the chapters entitled: The

The term *control* in the sense of a check or test observation or experiment came into scientific parlance in the latter half of the nineteenth century, as we shall see presently. By 1893 we find the *New English Dictionary* defining *control* as "a standard of comparison used to check the inferences deduced from an experiment by application of the Method of Difference," which is the name of John Stuart Mill's second method of experimental inquiry. The *New English* goes on to define *control-experiment* as "a test experiment with this end in view." So *control-experiment* was definitely in the language before *control groups* had been thought of, and this concept takes us back to Mill's four methods of experimental inquiry in his *Logic* of 1843.⁵

Mill's first method is the *Method of Agreement*: if *A* is always followed by *a*, then *A* is presumably the cause of *a*. Mere agreement does not, however, furnish rigorous proof, although you may be limited to it when you lack the voluntary variation of events—the independent experimental variable—and are reduced to description only. For this reason the establishment of causal relations in biography, history, geology, paleontology, and even astronomy is less sure than in experimental science. Mill remarked that mere agreement would indicate that night is the cause of day, and day the cause of night, since the sequence is universal, and he noted that we can be more certain that agreement indicates cause when the antecedent term in the conjunction of events can be established at will without dependence upon other events. Mill was right in mistrusting the Method of Agreement, since the concurrence of *A* and *a* in sequence may mean only that both are effects of the same sufficient cause, and, since if that other cause is sufficient but not necessary, it takes the Method of Difference to show that *A* and *a* are not necessary concomitants. It is for this reason that Mill suggested that the Method of Agreement is strengthened if *A* can be varied "at will," that is to say, if *A* is a freely independent variable. Such a caveat, however, actually constitutes an extension of the Method of Agreement to include the Method of Difference (when variation of *A* includes its elimination) or the Method of Concomitant Variation (when *A* is merely changed in degree). The inference of causation is never safe when based upon agreement alone.

The *Method of Difference* is Mill's second method: if *A* is always followed by *a*, and *not-A* is always followed by *not-a*, then *A* is certainly the cause of *a*. This is equivalent to adding the control observation: if *not-A*, then *not-a*. Mill used the word *control* once: "It thus appears that in the study of various kinds of phenomena which we can, by our voluntary agency, modify or control, we can in general satisfy the requisitions of the Method of Difference; but that by the spontaneous operations of nature those requisitions are seldom fulfilled." This use of *control* is, however, in

controlling environment; Self-control; Personal control; Group control; Economic control; Culture and control; and The problem of control. Certainly Solomon's *control group* has little relation to Skinner's *group control*. Even in discussion of experimental design the meaning of *control* is apt to vary. For instance, C. E. Buxton, in T. G. Andrews, *Methods of Psychology*, 1948, 73 f., in the course of two pages uses the word thrice as meaning maintenance of constancy of conditions and once in the sense of a test-observation.

⁵ J. S. Mill, *A System of Logic, Ratiocinative and Inductive*, 1843, Bk. III, chap. 8.

the sense of direction or guidance, whereas the Method of Difference provides *control* in the sense of a verifying check, although Mill did not make that use of the word. He recognized, however, the fundamental relation of his first two methods, speaking of the *Joint Method of Agreement and Difference*, which is essentially the modern scientific procedure for treating contingencies when continuities are not observed.

(The third method, the *Method of Residues*, need not concern us. If *ABC* is known to be the cause of *abc*, and *BC* the cause of *bc*, then *A* must be the cause of *a*, even though *A* can not be produced without *BC* nor thus *a* without *bc*.)

Mill's fourth procedure is the *Method of Concomitant Variations*. Nowadays we think of such observation as basic to all experiments and thus of Agreement and Difference as special cases of Concomitant Variation. Concomitant variation exists when there is a series of differences, and in any pair of concomitances one concomitance furnishes a comparison or control for the other. So we could get along with this method alone, if it were broadly enough conceived, except for the historical fact that the concept of control actually grew out of the consideration of the Method of Difference, which Mill's prestige established as independently important.

Mill is usually taken as the authority on this matter. Thought about these principles is, however, historically continuous. A century earlier Hume had a similar, less specific discussion, which laid down rules equivalent to the Method of Difference and to the Joint Method of Agreement and Difference.⁶ Still another century earlier Francis Bacon discussed the collection of data by the finding of instances that agree, and of negative instances and cases to furnish comparison.⁷ In these authors the anticipation of Mill is quite clear if one but remembers what a century or two can do to both thought and its expression.

At this point it is important to remark that every statement of fact expresses some kind of a difference. Even such description as is not experimental, being specific and thus discriminative, differentiates what is from what is not. Jevons offered as the formula for a fact: "Where *A* is, *X* is; and where *A* is not, *X* is not;"⁸ and that, of course, is also a statement of agreement and difference. Jevons remarked: "Every correct and conclusive experiment necessarily consists in the comparison of results between two different combinations of circumstances."⁹ It is plain then that in scientific description we are not going to get away from the concept of control, although the idea appears with different degrees of specificity and formality in statements of experimental design. If you have an observed datum, there is always some point or frame of reference in respect of which the datum makes sense, and it might aid clarity of thought if one were to think always of a datum set over against a relatum. (If *A*, then *a*) would be a datum, and (if *not-A*, then *not-a*) would be the relatum and the control observation, which might indeed depend upon a control-experiment to establish it. Again and again when agreement seems to yield certainty, it is because the control-observation is implied or even included in the experiment.

Now let us examine some instances of the use of the concept of control and of the word *control* in the scientific literature of the last one hundred years.

⁶ David Hume, *A Treatise on Human Nature*, 1739, Bk. I, pt. iii, sect. 15.

⁷ Francis Bacon, *Novem Organum*, 1620, Bk. II, Aph. 11-13, which deal respectively with the three principles.

⁸ W. S. Jevons, *Principles of Science*, 1st ed., 1874, II, 44; or 2nd ed., 1883, 433.

⁹ Jevons, *op. cit.*, 1874, II, 43; or 1883, 433.

Control as restraint or guidance. The meaning of *control* as restraint or guidance is the common, though later, meaning of the term, and in science it applies to keeping experimental conditions constant and also to altering the independent variable in accordance with precise known pre-determination. We do not need to hunt out instances of the scientific aspiration to keep conditions constant, to maintain controlled conditions or to vary a parameter under controlled conditions. In these contexts control, constancy and precision are of the essence of experimental science. Thus Titchener, in describing the nature of experiment, emphasized the necessity for repetition, isolation, and variation in the interests of good observation, constancy of conditions and exact variation, although he did not use the word *control*.¹⁰ In similar sense Murphy and Murphy have spoken of the "relatively uncontrolled observational and biographical studies" of children and the later "new experimental and highly controlled observation studies worked out" after 1915.¹¹ We can also go back to Fechner who sought constancy of conditions by control of experimental procedures and the treatment of data: "The arrangement of experimental conditions," he wrote, "the recording of observed values, the enumeration of errors or of right and wrong cases, as well as all the calculations based upon them, must be so arranged and controlled (controliren) by repetition and otherwise that, as far as possible, errors are avoided by the multiplication of data, by calculation when error is otherwise unavoidable, and by observing an immutable integrity in the recording and conversion of data."¹²

Control of the experimental independent variable, moreover, implies guidance as well as the maintenance of constancy, but the same admonitions and aspirations apply to this kind of control as to the control of conditions fixed throughout a particular experiment.

Control enters into psychic research with two different meanings. Holding hands and touching feet with each of your neighbors in the spiritistic circle may be thought to promote psychic continuity, but the practice also acts as a control against fraud. There is also, however, the *spirit control*, who or which guides and directs the

¹⁰ E. B. Titchener, *A Text-Book of Psychology*, 1910, 20; *A Beginner's Psychology*, 1915, 22-25. The only use of the word *control* that I can find in these books is in *Text-Book*, 22, where Titchener remarks that "experimental control is still possible" even when introspection interferes with consciousness.

¹¹ Gardner Murphy and L. B. Murphy, *Experimental Social Psychology*, 1931, 201 f., with examples of systematic arrangements for the recording of exact behavior and the maintenance of constancy of conditions on pp. 214-227.

¹² G. T. Fechner, *Elemente der Psychophysik*, I, 1860, 85; and there is another example of the use of the word farther down on the same page: "die Wiederholung oder sonstige Controle an sich langweiliger Operationen."

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