9

Thing Constancy as Measured by Correlation Coefficients [1940]

COMMENT

To Know an Experimenter

Elke M. Kurz and Ralph Hertwig

Whenever Brunswik researched perception, he simultaneously made psychological research itself an object of study. Brunswik was not a perception psychologist on the one hand and a philosopher of psychological methodology on the other; he was always both at the same time. This two-sided research agenda was his forte and his achievement; it constituted a challenge for his contemporaries, and it remains a challenge for us.

Common wisdom has it that "to know a man you should walk a mile in his shoes." We believe that it is equally true that "to know an experimenter you should replicate her study." For this reason we replicated the experimental study reported in the paper "Thing Constancy as Measured by Correlation Coefficients." This paper is crucial in Brunswik's work as it stands for the emigrant's attempt to relate his Viennese work to highly esteemed methodological tools of his new academic home. In this sense, this paper marks the transition between his Viennese past and his American future. Before we describe our replication of Brunswik's study, let us also appreciate his intellectual transition in relation to his biographical transition from Privatdozent at the University of Vienna to assistant professor at the University of California at Berkeley.

Constancies and Transitions

In August 1939, "Thing Constancy as Measured by Correlation Coefficients" arrived on the desk of Herbert S. Langfeld, then editor of *Psychological Review*, less than two years after its author had left Vienna and gone to Berkeley. How perceptual constancies can best be measured was a research question that accompanied Brunswik from his old to his new academic home. The term *thing constancy* is a literal translation from the German term *Dingkonstanz*. Thing constancy, or perceptual constancy, is our tendency to perceive size, color, shape, loudness, and other features of our surroundings as relatively constant despite changing projections on perceptual surfaces. Size constancy, for instance, entailed that "for a somewhat developed human being, an approaching visitor will not grow from a finger-like dwarf up to an immense giant, but will, within certain limits, quite fairly retain a constant apparent size" (Brunswik, 1937, p. 228). In Vienna, Brunswik had measured perceptual constancy of various sorts using a *constancy ratio*. This measure was of his own creation (Brunswik, 1928; for a definition, see p. 189, and also our Figure 9.2) and became subsequently known as the *Brunswik ratio* (e.g., Woodworth, 1938, p. 864).

At the University of California, Brunswik had an influential supporter, Edward Tolman. In a letter to the vice president and provost of the university dated December 2, 1937, Tolman wrote "that it would be not far short of a crime for the University to let him [Brunswik] go." They did not commit this crime, and Brunswik accepted a position there in 1938. Else Frenkel, a colleague at the Vienna Psychological Institute, came to the United States, and she and Brunswik were married that year. In other respects these were, of course, not happy times. Austria was annexed to Nazi Germany in 1938, and Adolph Hitler's plans of persecution, aggression, and war were painfully apparent. Brunswik also worried about his former advisers, Karl and Charlotte Bühler, who had been forced to emigrate (Ash, 1987). In a letter addressed to Walter Miles at Yale University, dated April 22, 1938, Brunswik inquired about the "chance to place them." In the same letter, he indicated that he was going to send "this same letter to a small number of other psychologists who [he thought] might be particularly interested in the Bühlers" (*Archives for the History of American Psychology*, Ms. #1134). These efforts to assist his mentors were not met with particular success.

In Berkeley, Brunswik (1937) prepared an English presentation of his Viennese research program. This program was a sophisticated continuation of Karl Bühler's theoretical positions. According to Bühler's duplicity principle, constancy phenomena were the result of at least a "two-fold stimulus-basis" (Brunswik, 1937, p. 111; see Doherty & Kurz, 1996). After 1937, this research program became subjected to a probabilistic "breeze." Brunswik participated, for instance, in a "statistical discussion group" with colleagues at the psychology department (p. 191, footnote 5). Eventually, in his paper of 1940, Brunswik introduced correlation statistics to his perception research, then he carefully weighted the pros and cons of his new and his old ways of measuring thing constancy.

Brunswik's paper of 1940 was in many ways just a beginning. The work that Brunswik carried out after his move to Berkeley reflects his process of immigration. In this process, "old" and "new" cultures are compared and evaluated in order to achieve an integration. Brunswik became an American citizen in 1943. Two years later, he participated in the first University of California Symposia on Mathematical Statistics and Probability, with a paper that was later, in 1947, published as "Systematic and Representative Design of Psychological Experiments" (and posthumously, in 1956, republished as Part I of his book *Perception and the Representative Design of Psychological Experiments*). This paper represented, as he phrased it, his "bringing to convergence European academic with Anglo-American statistical tradition" (Brunswik, 1947, p. 56). Premonitions of this intellectual integration were already present in his paper of 1940 (p. 191), which ended with a statement that revealed his clear sense of direction: "The author's ultimate aim is to establish a multidimensional psychophysics which will include the distal environment within its scope."

Berlin "Replicates" Berkeley

Our original motive for replicating the study reported in "Thing Constancy as Measured by Correlation Coefficients" was to "walk in Brunswik's shoes." But to be honest, we also harbored some disbelief concerning an effect that we noticed in his data. To our surprise, participants' performance revealed consistent overestimation of physical size (compare the *b*s and *e*s in Table 9.1, p. 187, where *b* stands for body size and *e* for average estimate). Would we find the same clear-cut overestimation effect with our replication?

We structure the presentation of our replication according to the rationale of present-day APA format. Brunswik's original paper, however, was organized differently; it consisted of three main sections numbered I, II, and III. The first gave a report of his laboratory study, including a rudimentary version of his later lens model (see Kurz & Tweney, 1997). In Part II, he analyzed and compared his new and his old measures of achievement, by and large coming out in favor of correlation. The third section was dedicated to the pragmatic aspects of his new tool, showing how his use deviated from the tool's more-or-less conventional use. We superimposed APA format on Brunswik's study in order to accentuate those aspects of Brunswik's practice that deviate from our present-day expectations. In our presentation, *Berkeley* signifies Brunswik's study of 1940, *Berlin* our replication of 1998.

Hypotheses

Berkeley

No explicit hypotheses were stated or formally tested. As indicated by the title of the paper, Brunswik's aim was measurement.

Berlin

Initially, we were surprised at the consistent overestimation of size reported by Brunswik. We would have expected some more-or-less random variation of the estimates around the body sizes of the cubes. We quickly figured out that such an overestimation effect was consistent with Brunswik's Viennese theory of in-between-objects. This theory postulated that estimated size lies in between body size and proximal size. (Note, that we use *projective size* and *proximal size* interchangeably.) It follows that size is overestimated whenever projective size is larger than body size, which was the case for all cubes in Brunswik's experiment (compare the *b*s and *p*s in Table 9.1, where *b* stands for body size and *p* for projective size). Projective size was larger because of the following considerations. For example, given a cube with an edge length of 70 mm at a distance of 10 m, its projective size measured in degrees of visual angle is equal to the projective size of a comparison cube of 84 mm at a distance of 12 m. Because the comparison series was at a larger distance from the observer than the cubes that had to be estimated, and because projective size was determined with respect to the distance of the comparison series it followed that projective size was larger than body size for all cubes. Brunswik's theory of in-between-objects made a clear prediction and was clearly corroborated by his results.

Method: Participants

Berkeley

"Eight students were used as observers, each of them running through the experiment only once" (p. 188). Brunswik averaged their estimates and then reported only the values averaged across the participants.

Berlin

Eight researchers from the ABC research group at the Max Planck Institute for Human Development were used as observers, each of them running through the experiment once. (The entire ABC group was rewarded with cake at coffee time when the results were presented.)

Materials

Berkeley

> A set-up of 15 cubes made of natural hardwood, ranging from 50 to 70 mm, was presented to the observers at frontal planes of 2, 4, 6, 8 and 10 m distance, three cubes at each distance. The lateral distance between neighboring cubes was approximately 80 cm. In the rear of the room, at a distance of 12 m from the observer, a comparison series of 13 cubes ranging from 30 to 90 mm with step-intervals of 5 mm was set up. All objects were placed on tables of usual height. The observer was seated on a slightly elevated chair and so had a complete view of the set-up. The sizes and distances of the cubes are schematically represented in Table 1 (p. 187; a more elaborated version of Table 9.1 can be found in Brunswik, 1956b, p. 68).

The experimental arrangement of the cubes kept the correlation between distal stimuli (the *b*s) and proximal stimuli (the *p*s)—that is, between body sizes and projected sizes—at a low value and, as Brunswik (p. 188) remarked, "could, as *e.g.* for the purpose of a further demonstration, easily be brought down to zero."

Berlin

The only room spacious enough for this setup at the Max Planck Institute for Human Development was a large conference room. Given the distribution of windows in this room, its space was not evenly lit. We turned on all the lights and even brought in an additional lamp to approximate evenly distributed light conditions. (When setting up the experimental arrangement, it became apparent to us that this study could only have been conducted by a person who loved measurement.)

A participant in a pilot run pointed out that the comparison task was complicated by the necessity to count the cubes in the comparison series in order to name their respective number. We therefore numbered the comparison cubes on a banner mounted on the wall behind the comparison series.

Procedure

Berkeley

"The observer was asked to take a natural unconstrained attitude, and to match each of the 15 cubes with the comparison series. . . . The order of the judgments was systematically varied from observer to observer" (p. 188).

Berlin

For the instructions that would induce "a natural unconstrained attitude" we consulted Brunswik's paper of 1944 (p. 4, "naive perceptual attitude"). Before the participants entered the conference room, we showed them a schematic representation of the experimental arrangement, similar to the elaborated version of Table 9.1 shown in Brunswik (1956b, p. 68). With the instructions, we emphasized that physical size should be the basis for their judgment; we even showed two cubes of equal size during the instruction phase.

Each participant was asked to make fifteen judgments. The experimenter specified a particular cube in the array (e.g., third row, middle cube), and the participant answered by giving the number of the cube in the comparison series that matched the specified cube in physical size. The experimenter specified the cubes in random order; the order was different for each of the eight participants.

Results

Berkeley

The data in Brunswik's study of 1940 were the estimates of cube size as determined by participants' choice of corresponding comparison cubes. For each of the fifteen cubes, an average estimate, *e* (averaged across the eight participants), was reported in Brunswik's Table 9.1. In his Table 9.2, he presented the "correlations among distal stimuli, proximal stimuli, and perceptual responses" (p. 188). The correlation between proximal stimuli and perceptual responses was $r(ep) = .26$, whereas the "distal correlation, directly expressing far-reaching perceptual achievement" was as high as $r(eb) = .97$. Brunswik did not mention it explicitly, but size was consistently overestimated in the averaged data he presented (see our Figure 9.2).

Berlin

Did we replicate Brunswik's findings? Yes and no. Yes, because we obtained nearly identical correlations: The correlation between proximal stimuli and perceptual responses, $r(ep)$, was .21, and the correlation between distal stimuli and perceptual responses, $r(eb)$, was .98. No, because we did not replicate the systematic overestimation effect he found. Rather, as the average estimates in Figure 9.1 show, we found (1) underestimation in three cases, (2) perfect calibration of the estimate in one case, and (3) in the remaining cases, merely slight overestimation. The interesting point here is not that our colleagues at the ABC group performed better than Brunswik's Berkeley participants but that the calculation of correlation coefficients is not sensitive to such substantial reduction in error.

A pattern of results similar to the one we obtained on the aggregate level was also observed on the level of the individual estimates. Out of a total of 120 estimates (eight participants estimating fifteen cubes) cube size was underestimated in twenty-eight cases, was accurately estimated in thirty-eight, and was overestimated in fifty-four cases. It should be added that the participants in Berlin overestimated cube size in no case by more than 15 mm or underestimated cube size by more than 10 mm, which corresponds to choosing three or two cubes, respectively, to the left or right of the matching cube in the comparison series. The data reported by Brunswik do not allow for a corresponding analysis on the level of individual estimates.

Why is there such a discrepancy between Brunswik's and our findings concerning the estimates' precision? Here, a study by Beverley E. Holaday may indicate a possible answer. Holaday was an American student at the University of Vienna in early 1930. It is interesting to note that Brunswik served as participant in Holaday's study, and he also edited Holaday's paper for the *Archiv für Psychologie*. Holaday (1933) manipulated multiple variables and combinations thereof and studied their impact on perceptual size constancy. He had no less than twenty-eight experimental conditions! Based on these results, Holaday established a rank order of experimental

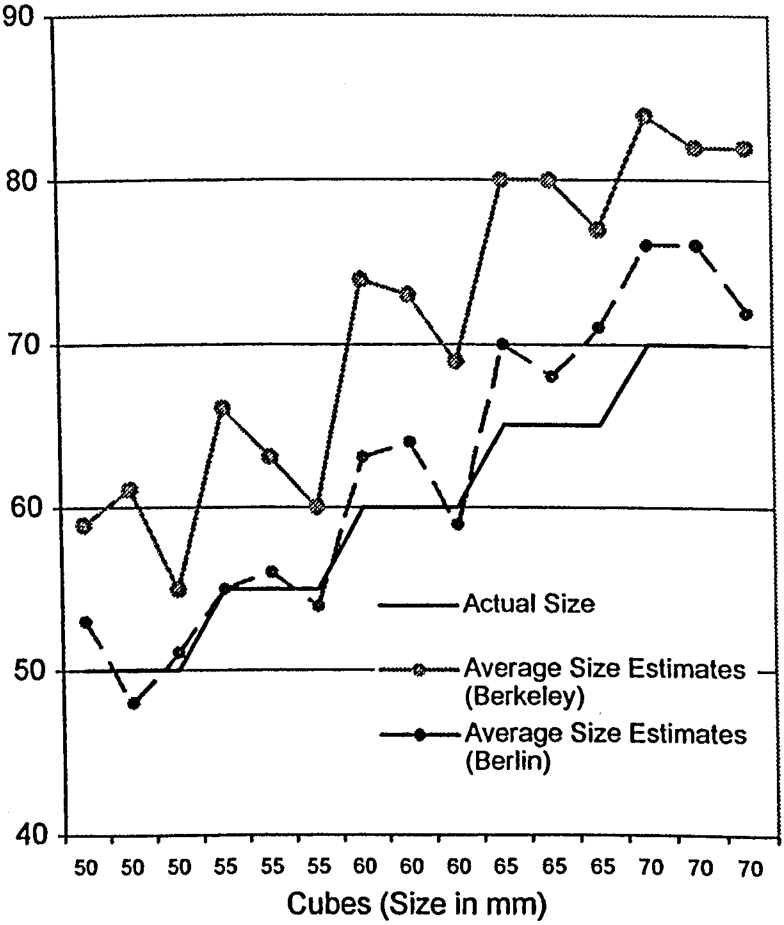

FIGURE 9.1 Average estimates of cube size obtained in Berkeley and Berlin. The cubes are ordered according to their actual size, and within each size category (e.g., 50 mm), the cubes are ordered according to their distance from the observer (starting with the nearest cube).

conditions according to a constancy ratio index. What is relevant to the discrepancy between Brunswik's and our findings is that the average value for the constancy ratio that we determined in our replication is about comparable to the value Holaday (1933) reported for "critical attitude," an attitude that Brunswik characterized as follows (1944, p. 4): "Take the attitude you would have, if you were to bet upon the sizes in question to the best of your knowledge." Brunswik repeatedly pointed out the importance of instructions in constancy research (e.g., Brunswik, 1947, p. 20). Although we attempted to induce a naïve perceptual attitude via our instructions, we may have failed in the ecology of our lab, in which betting is part of the lab culture.

Discussion

Correlation Statistics

Brunswik's use of the correlation coefficient to measure achievement was unconventional—and was met by harsh resistance—because it divorced correlation statistics from the study of interindividual differences (Gigerenzer, 1987). The correlation coefficient first emerged from Francis Galton's studies of anthropometric data, more specifically, of interindividual differences in the relation between height and forearm length (Stigler, 1986). In psychology, correlation statistics remained pragmatically linked to the measurement of interindividual differences, to the point where psychology was split into two more-or-less unrelated disciplines, the "correlational" and the "experimental." In the late 1930s, Brunswik began to use the correlation coefficient for the quantification of perceptual achievement and mediation—in complete disregard of interindividual differences.

In his paper of 1940, Brunswik went so far as to average the estimates of eight participants and then to consider this average "as the result of one single experiment with *one observer only*" (p. 188, italics added; see above "Participants: Berkeley"). Brunswik removed—so to speak, with one stroke—variation between participants from consideration (a practice considered unacceptable today, although still frequently used). But note the context, Brunswik's intention was to liberate an established tool from its familiar context (the study of interindividual differences) and to make it serve a new purpose (the measurement of achievement).

Achievement

In 1940, Brunswik characterized his Viennese understanding of achievement as "the degree of perfection of *the constancy mechanism*" (p. 189, italics added). Achievement meant the degree to which the perceptual system was able to move its response from the proximal stimulus. Thus, achievement was relative only to the proximal stimulus, not—yet!—to the distal environment. This understanding of achievement was reflected by his constancy ratio. In the case of size perception, the ratio related the differences between estimated size and projected size and between body size and projected size. The third possible difference—namely, that between estimated size and body size (the errors)—had not been formally considered in his Viennese program (see Figure 9.2).

In Berkeley, achievement became measurable by a "distal correlation" (p. 188). Thus, the environment was no longer "distant" (p. 187) but had become measurable in its relation to "the perceptual system—or the organism in general" (p. 191), and hence epistemologically closer. The relation between perceptual response and distal stimulus (the distal correlation r_{eb} in Figure 9.2) was now treated on a par with the relations of response and distal stimulus to the proximal stimulus (the correlations r_{ep} and r_{bp} in Figure 9.2).

However, as with the old measure, correlation did not take the *amount* of deviation of judged size from actual size—that is, of error—into account. This design feature of the correlation coefficient was nicely revealed in our replication of Brunswik's study. Although we replicated Brunswik's reported correlations almost identically, our participants were much better calibrated than his. Brunswik himself seems to have realized this limitation of correlation statistics. Already in his paper of 1941, he included systematic error analysis in his constancy research. Later, in his contribution to a Symposium on Personal and Social Factors in Perception held during the 1949 meeting of the *American Psychological Association* in Denver, he expanded his use of error analysis to distinguish perceptual and reasoning processes.

To Know an Experimenter . . .

While preparing our replication of Brunswik's (1940b) study, we sought answers to questions that we could not find answered in his paper. Among those questions was, for instance, whether we should correct for differences in body size of the observers by adjusting the height of the swivel chair on which the participants were sitting. Brunswik's paper shows nearly complete absence of such procedural concerns. We see two reasons for his "disregard." First of all, the paper of 1940 was not meant to be a research paper, in the sense of being a detailed report of a particular laboratory study of size perception (see Brunswik, 1940b, p. 190). Rather, the paper was a "sketchy beginning, with the purpose of demonstrating a general principle," namely, how correlation analysis "deals with both the distal and the proximal" (p. 190). Second, we believe that the absence of such concerns also reflects Brunswik's developing opposition to the "classical" ideal of experimental control.

Brunswik came to be convinced that the "classical experiment," which "has been handed down

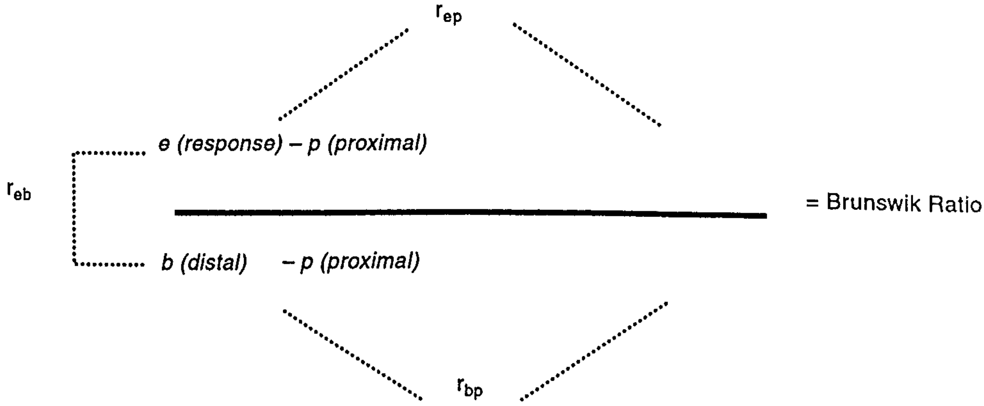

FIGURE 9.2 Correlations among distal stimuli, proximal stimuli, and perceptual response and how they map onto Brunswik ratio. In 1940, Brunswik used *e* to denote estimate, *p* to denote projected size, and *b* to denote body-size. He also refered to *e* as the perceptual response, to *p* as the proximal stimulus, and to *b* as the distal stimulus.

to us from such famous origins in physics as Galileo's study of the fundamental laws of falling bodies" (Brunswik, 1947, p. 8), was of limited utility to the experimentalist in psychology. For him, the "classical formula" in the context of psychological experimentation meant the following (1947, p. 9): "All relevant external conditions (and there are supposedly not too many) to be systematically controlled, all internal conditions to be treated quasi-systematically by computational elimination of random variability." Brunswik's opposition is nicely illustrated by the annotations that he made in his copy of Woodworth's (1938) *Experimental Psychology* (which, thanks to Kenneth Hammond, the Brunswik Society, and Ryan Tweney, will be preserved at the Archives for the History of American Psychology, Akron, Ohio). On page two of Woodworth's text Brunswik doubly underlined the phrase "he [the experimenter] holds all the conditions constant except for one" and commented in fine pencil "*imposs!*" (see for a reprint of this page with Brunswik's annotations Kurz and Tweney, 1997, p. 228). Consequently, Brunswik had also a low regard for the "autocratic experimenter" (Brunswik, 1944, p. 35). And he fully endorsed the idea that "modern experiments on thing constancy are deliberately 'poorly controlled' with respect to cues, when viewed from the standpoint of the classical experimentalist" (Brunswik, 1947, p. 23).

We have come full circle. Brunswik was not a perception psychologist on the one hand and a philosopher of psychological methodology on the other—he always was both simultaneously. His study of 1940 introduced the distal environment into his perception research, and as a consequence, he had to rethink psychology's notion of the experiment. Crucial steps of Brunswik's rethinking of experimental methodology after 1940 may be traced in his paper "Distal Focussing of Perception: Size-Constancy in a Representative Sample of Situations" (1944). But here again, it may be the case that "to know an experimenter . . ."

NOTE

We wish to thank Gerd Gigerenzer, Wolfgang Hell, Laurence Fiddick, Martin Lages, and Anita Todd for their comments on earlier versions of this paper.

REPRINT

Thing Constancy as Measured by Correlation Coefficients

Egon Brunswik

The term 'perceptual thing constancy' is applied wherever a certain type of perceptual response is found, under ordinary circumstances, to vary concomitantly with a certain kind of physical property of distant, or 'distal,'[1] environmental bodies (such as size, shape, reflectivity to light) rather than with the actual 'proximal' stimuli directly elicited by such distal properties, either on the retina or on some other receptor surface of the organism. The classical quantitative expression of co-variance between any pair of variables is the correlation coefficient. The present paper attempts to demonstrate, in a quite preliminary and non-technical fashion, the use of correlational analysis as a means of representation of the degree of perfection of perceptual thing constancy. As our example we have chosen, in the field of size-constancy, an experiment which was especially designed for the purpose.

I

A set-up of 15 cubes made of natural hardwood, ranging from 50 to 70 mm, was presented to the observer at frontal planes of 2, 4, 6, 8 and 10 m distance, three cubes at each distance. The lateral distance between neighboring cubes was approximately 80 cm. In the rear of the room, at a distance of 12 m from the observer, a comparison series of 13 cubes ranging from 30 to 90 mm with step-intervals of 5 mm was set up. All objects were placed on tables of usual height. The observer was seated on a slightly elevated chair and so had a complete view of the set-up. The sizes and distances of the cubes are schematically represented in Table 9.1. The measured size of the cubes which is the distal stimulus and is labeled b (body-size) is indicated in bold-faced type. As

TABLE 9.1 Experimental Arrangement (Raw scores in italics)

Distance from observer (meters)		*Data on the cubes (in mm)*		
12		Thirteen comparison objects with sizes ranging from 30 to 90 mm		
	b	70	55	50
10	*e*	*82*	*60*	*55*
	p	84	66	60
	b	55	60	70
8	*e*	*63*	*69*	*82*
	p	83	90	105
	b	65	50	65
6	*e*	*80*	*61*	*77*
	p	130	100	130
	b	60	70	55
4	*e*	*73*	*84*	*66*
	p	180	210	165
	b	50	60	65
2	*e*	*59*	*74*	*80*
	p	300	360	390
		Position of observer		

can be seen, there are three cubes each of 50, 55, 60, 65 and 70 mm height, randomly distributed over the whole field.[2]

The figure in ordinary print, placed in the third row of each group of figures, indicates in each case the proximal stimulus value, that is to say, the actual retinal or 'projective' size *p* of the cube in question, in terms of the comparison series as related to the actual position of the observer. For example, the left rear cube, size 70 mm and at a distance of 10 m, occupies the same space on the retina of the observer as would an 84 mm cube at the distance of the comparison series, 12 m. Similarly, the right front cube, size 65 mm, is projectively equal to a 390 mm cube at 12 m distance; and so on. The values indicated are only approximate since lateral distortion has not been

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taken into account. This latter, however, from the point of view of our purpose, is of minor importance.

The observer was asked to take a natural, naive and unconstrained attitude, and to match each of the 15 cubes with the comparison series. Eight students were used as observers, each of them running through the experiment only one. The order of the judgments was systematically varied from observer to observer. The italicized figures in the middle of each group of figures give the perceptual (verbal) responses, namely the average estimates, *e*. For the purpose of our paper they may as well be considered as the result of one single experiment with one observer only, since at no stage of our considerations will the matter of individual or of time differences be considered nor will the correlation technique be applied to these latter.

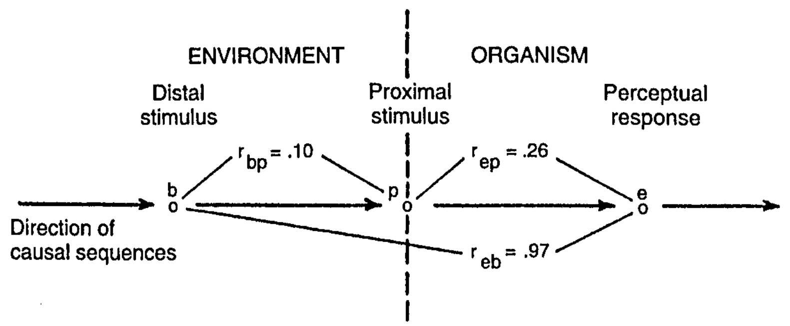
In each of our fifteen instances, *e* is in an intermediate or 'compromise' position between *b* and *p*, usually much closer to the former than to the latter. This way of reacting is typical of most constancy experiments performed under ordinary conditions, yielding what has been labeled the phenomenon of 'approximate size constancy.' We may express the degree of this approximation by computing correlation coefficients between the three sets of variables.[3] The result is given in Table 9.2.

Two of these three coefficients contain the response-variable, *e*. *They indicate that estimated size shows a much higher degree of concomitant variation with the size of the distal environmental bodies than with the size of their projections upon the retina though these latter, are essential in conveying body size to the organism.* The fact that r_{eb} is not unity, and r_{ep} not as low as r_{bp}, is an expression of the lack of perfection of the constancy mechanism, which gives *p*, per se, an exaggerated emphasis.

The third coefficient, r_{bp}, has nothing to do with the observer's response but is concerned rather with the purely external interrelationship between the size of the distal body and the size of its retinal stimulus representation. This coefficient is very low. Indeed, when taken by itself, *p* is a very 'unreliable' cue for the size of the body 'causing' *p* (*cf.* 5, 6, 19). Due to the fact, however, that large objects placed at various distances will on the whole elicit somewhat larger retinal images than small objects at similar distances, the correlation is not quite as low as would seem to be desirable from the standpoint of an experiment such as ours, *i.e.*, it is not quite zero. Since this tendency in our case (as often in nature) is insignificant in comparison to the distorting influence of the difference in distance, r_{bp} is low enough to be discarded in a first approximation. By slight changes in the arrangement it could, as *e.g.* for the purposes of a further demonstration, easily be brought down to zero.

The fact that the distal correlation *eb*, directly expressing far-reaching perceptual achievement, is high whereas the two correlations containing the mediating proximal link *p* are low may, when taken by itself, seem paradoxical. The answer is, of course, that something has been left out of the picture, namely a group of proximal stimulus feature more or less correlated with the distance between object and observer which, duly brought together with *p*, will functionally explain the presence of a high correlation between *e* and *b*. The fact remains, however, that the proximal

TABLE 9.2 Correlations among Distal Stimuli, Proximal Stimuli, and Perceptual Responses



stimulus configuration mediating this correlation, or the constituents of this configuration, show a high degree of variability and flexibility, whereas e and b do not, and thus it is these latter which stand out as focal points of perceptual or organismic activity in general. It is these focal points, usually of vital importance, in the near or remote environment upon which a molar psychology should concentrate its efforts. A supplementary consideration of the general character and of the degree of the flexibility of mediation as expressed by low mediational correlations will help to complete the picture.

II

In recent years the degree of perfection of the constancy mechanism has repeatedly been represented by means of a constancy ratio, c, introduced by the author (3), whereby

$$c = \frac{e-p}{b-p}.$$

By the use of this formula, the degree of constancy can be computed for each of our cubes separately, yielding 15 c-values. They tend to be higher for the cubes near the observer than for those farther from him (for reasons which are of little bearing here). If computed from the logarithms of e, b and p instead of from the numerical values (*cf.* 17, p. 344; 4, p. 391), their average is .69.

The constancy ratio has several practical advantages. It is applicable, in principle, to any single pair of cubes set up at different distances and judged by an observer as equivalent with regard to apparent size. Furthermore, it expresses the constancy-achievement by one single index, c, relating e to both b and p at the same time. And it does so in such a way that the fixed values $c = 0$ and $c = 1$ always represent the same kinds of outstanding achievement, namely complete lack and complete perfection of perceptual constancy, respectively.

The correlational technique suggested above possesses none of the advantages. It requires a whole set of bodies of various sizes and at various distances (not to mention requirements regarding the frequency distributions of these sizes and distances). These objects have either to be ranked among each other, or matched to a common scale, as was done in our experiment. The degree of achievement, or its contrary, deviation from the correct judgment in a certain direction, appears in distinctness only after a joint inspection of all three of the coefficients has been made, or only after some new index has been evolved. (In the simplest and crudest possible case, the latter could, for instance, be the difference between r_{eb} and r_{cp}, .71; which, by the way, in our particular case would be very similar to our average c-value, .69.)

On the other hand, as the author has pointed out previously (4, 5), the constancy ratio is too much bound up with certain rather incidental aspects of the experiment, such as the physical dimension in which the stimulus-situation is varied. It is of little use when the interplay of more than two variables is to be considered, and it does not isolate sharply the character even of these two variables (*cf.* 5, 1). It is not limited to values between the ideal poles 0 and 1. For example, values above 1 also indicate deviations from perfect constancy as do those below 1 though in a different direction. This shortcoming has been especially emphasized by Koffka (12, pp. 227, 234).

In contrast, the use of correlation techniques, though clumsier at first sight, is an approach of much more basic significance. It brings the constancy problem within the scope of the standard instrument developed to disentangle complex causal textures of whatever nature. It helps in the giving up of the exclusive search for strictly univocal correspondences, in psychophysics as well as in stimulus-response psychology in general, by rendering more legitimate the carrying over from the psychology of individual differences to these disciplines of what the author would like to call a 'deliberate lump-treatment' (7).

In doing so our approach goes beyond 'multidimensional psychophysics' of the merely proximal type, represented, for example, by the studies of Stevens (16, p. 70 *ff*; *cf.* also 20, p. 509), or Richardson (13). In this latter fairly recent type of research a perceptual response (such as the apparent loudness of a tone) has been studied as a function of more than one stimulus-variable (such as the frequency as well as the intensity of the underlying sound wave). Though the relationships found may justly be called complex and thus in a certain respect lacking univocality, yet the scope of such studies remains limited to the strictly lawful relationships which hold between a complex of proximal stimulus features and the response. Our aim, on the other hand, is to expand the investigation, regardless of the lack of a perfectly reliable representation of distal events in the proximal region, into the distal environment.

In so widening our scope, we are enabled to determine statistically the distal (along with the proximal) factors upon which the perceptual system has become fairly well focalized and which thus have become virtually the most effective determiners of the response. It is this type of far-reaching stimulus-response correlation which Holt (11, pp. 161 *f.*) and Hobhouse (9, p. 15) had in mind (*cf.* Heider, 8) and to which even earlier objective psychologists like Bechterev (2, p. 17) and Watson have occasionally referred, in an abstract way, and yet failed to deal with concretely, due to the difficulties caused by the lack of perfection inherent in such couplings.

This whole procedure should not be conceived as being limited to problems of perception, and to the use of correlation coefficients in the technical meaning of the term. Problems of overt behavior such as the obtaining of food by an animal are just as capable of quantitative correlational analysis of the relative importance of proximal and distal effects.

III

Our method differs from the most common use of the correlation coefficient in that the role of the individuals tested is taken over by the objects in the physical environment of a certain individual organism, and the role of the tests applied to the individuals is taken over by various (in our case three) kinds of manifestations, or effects, of these objects, namely size as measured by applying a meter-stick directly to the object (*b*), size of the effect of the object on the retina of the organism in question (*p*), and size as it is perceptually anticipated by that organism (*e*).

Thus our method has little in common with the modification of procedure suggested by Stephenson (15), who interchanged individuals and tests, and whose method thus, in contrast to ours, remained in the realm of individual differences.

Likewise, our method differs from the application of the correlation technique and of factor analysis to any combination of distal perceptual tasks such as occurs in the studies of Thouless (18), Sheehan (14, pp. 52–56), and Hofstätter (10, pp. 27–33). There again the concern was with factors within the personality determining individual differences in perceptual achievement whereas the determining factors in our case are of an environmental nature.

As has been mentioned above, our method also transcends proximal multidimensional psychophysics, in that it includes the testing of distal determinants. It thus may become a tool for what might be called distal (and multidimensional) psychophysics.

In a certain way related to our approach are cases like that of Woodworth (20, p. 251) in which the emotions as expressed on a person's face have been correlated with judgments of these emotions given by a group of observers. The emotional state of another person is an environmental feature even a step farther distal than the size of a body. The chief difference when compared to our procedure lies in the fact that in the case just mentioned the distal stimulus only is considered, and the more proximal representations neglected. The same holds for cases in which the intelligence of a group of persons has been correlated with intelligence as judged from photographs of these persons.

Our procedure, on the other hand, deals with both the distal and the proximal, the achievemental and the mediational aspects. The outcome may lead to subordinating the latter to the former, but as far as the procedure is concerned both are taken into account and their relationship is examined.[4]

This article is no more than a sketchy beginning, with the purpose of demonstrating a general principle. All questions of detail and the further development of the statistical procedure such as the application of the analysis of variance, the isolation of the effective environmental factors, the fulfillment of the requirements for the application of the standardized correlational methods (such as normal distribution of the variables, etc.) and their possible modifications, the question of reliability of measures, etc., will have to be discussed in further publications of a more technical nature.[5]

Summary

An example has been given from the field of perceptual size constancy of the way in which

correlational analysis may be helpful in determining quantitatively the degree to which the perceptual system—or the organism in general—is successful (under ordinary circumstances) in giving a specific response to, or in focalizing upon, a certain feature of the remote physical environment in spite of disturbances resulting from the incidental character of the proximal (retinal) stimuli mediating these distal environmental features. And it appears as characteristic of the constancy mechanism that high correlations of the response with distal factors may be accompanied by low correlations with the mediating proximal cues. The author's ultimate aim is to establish a multidimensional psychophysics which will include the distal environment within its scope.

NOTES

1. This term, recently adopted in this connection by Heider (8), is less open to misunderstanding than the term 'distant' which has too narrow spatial connotations.

2. Thus size constancy in this case might have been spuriously supported by 'central tendency' imposed by the comparison series. There is however sufficient evidence from other studies that this factor is not a decisive one.

3. Since our concern is only with demonstrating the principle, the numerical values given in Table 1 have been used in computing these correlations, instead of the probably more preferable logarithms of these values.

4. In a recent article (8), Heider has interpreted the author's conception of a 'psychology in terms of objects' as being limited to the distal aspects with exclusion of the proximal. Actually, this is not the case. Foci of correlations with organismic events will be recognized wherever they may be found, in the proximal as well as in the distal environment. Furthermore, even in the case of distal foci there is interest in the proximal aspects of mediation. This concern is best shown by the positive assertions made in this paper about the lowness of the correlations holding for a certain type of proximal events.

5. The author is being aided in this work by a statistical discussion group under Professor Tryon. Some of the special problems will be worked out in collaboration with Mr. Robert Gottsdanker.

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