zoa, of solenocytes structurally similar to those of *Priapulus caudatus* does not necessarily indicate a primitive organism but rather a retention of a primitive type of excretory system. To affirm homology for the proboscis apparatus of Acanthocephala and Priapulida, when embryology is unknown, is rash. The apparatus is different morphologically and functionally in both groups. The tissues present, as well as their arrangement, suggests that in the Priapulida it is probably derived, in part, from ectoderm, while in the Acanthocephala it is probably derived from mesoderm. The stereogastrula of *Priapulus caudatus* is unciliated and oval, and it consists of an inner syncytial cellular mass and an outer single layer of ectodermal cells (*1*). The priapulid stereogastrula is a simple postgastrula, while the earliest larval stage of the Acanthocephala and the Kinorhyncha are considerably more complex and advanced.

For these reasons a comparison is valueless. The larval stage of the Acanthocephala, described by Lang as possessing great resemblance to the stereogastrula, is in fact only a theoretical transitory stage in the development of the acanthor larva which does not pass through distinct blastula and gastrula stages. Simplicity of form is the greatest similarity of these three larvae, but this feature is common to the early developmental stages of all animals.

Histological evidence indicates that the Priapulida should be placed somewhere among the coelomate groups of animals. As vermiform coelomates, priapulids are unique. They possess a cuticle that is not only molted periodically through the adult life, but which has been determined chemically (*4*) and by x-ray diffraction studies (*5*) to be in part chitin. The caudal appendage, which is an extension of the coelom, and which is found in five of the six species in the "phylum", is unique. The Priapulida also possess an eversible proboscis. When all these factors are considered, the Priapulida are seen to constitute a very distinct group, perhaps deserving the status of phylum (*6*).

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References and Notes

1. K. Lang, *Arkiv Zool.* **5**, 321 (1953).
2. L. Hyman, *The Invertebrates* (McGraw-Hill, New York, 1951), vol. 3.
3. ———, *ibid.* (1959), vol. 5.
4. D. Carlisle, *Arkiv Zool.* **12**, 79 (1959).
5. W. Shapeero, in preparation.
6. I gratefully acknowledge the assistance of D. Ray and K. Osterud, department of zoology, and J. Lynch, College of Fisheries, University of Washington.
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Human Vigilance and Operant Behavior

Abstract. The analysis of vigilance as operant behavior treats illumination (observing) responses as operants that produce signal-detections. Evidence is presented that the relationship is an artifact of the procedure, and that no vigilance factor is involved in illumination-responses.

Human vigilance, defined by the capacity to detect rare, near-threshold signals, shows orderly changes as a function of time at work, signal-to-noise ratio, and other conditions (*1*). For the psychologist it is an aspect of the general problem of attention or alertness. It is of special interest to the human factors specialist, because vigilance is a major performance factor in monitoring displays that signal the state of malfunction of automated equipment.

Holland (*2, 3*) proposed a technique for studying vigilance by using "observing responses"—that is, an observer's operations of a switch to illuminate the display—and showed that observing responses follow signal schedules the way other operants (*4*) follow reinforcement schedules. He also showed a good correspondence between observing response frequencies and detection frequencies. From this he concluded (*3*, p. 67) that "the detection data of vigilance studies may reflect the observing response rates generated by the particular schedules employed." The present report (*5*) tests this conclusion with a correlational analysis to determine the extent to which common factors govern variations in detection rates and observing response rates.

A paper by Baker (*6*), which appeared after the present work was completed, showed that observing responses, defined by photographic records of eye-fixations toward the display, did not behave as Holland's observing responses and were not correlated with detection rates. Rather than refuting Holland's argument, however, this result seems to us to indicate that such eye-fixations cannot be observing responses. Any reasonably defined observing response must, after all, result in a detection when it accompanies a signal. Baker's result suggests that one can appear to be looking at something without observing it. To avoid semantic confusion, Baker's responses should be called "eye-fixations," and Holland's, "illumination-responses," reserving the term "observing response" for an as-yet-unspecified act that accompanies the detection of a signal.

Signal-detections are, by definition, measures of vigilance, and our question is: are vigilance factors in signal-detections also present in illumination-responses? This can be answered simply by examining the correlation coefficients in an experiment in which the same observers perform a vigilance task twice, once with and once without the illumination-response requirement. A "vigilance" factor would be reflected in the expected significant positive correlation between signal-detections in the two performances (see *7*). If the same factor is also involved in illumination-responses, there should be a similar correlation between those responses and signal-detections in *both* performances.

The results of such an experiment are shown in Fig. 1. The apparatus used was a Mackworth-type clock (*8*) on which signals were 20° steps of the pointer that replaced 1/second 10° steps at programmed inter-signal intervals averaging 138 seconds and ranging from 52 to 203 seconds. Sixteen paid male undergraduates, working individually, monitored the clock during two uninterrupted 92-minute sessions on different days. One session required illumination-responses; in the other, the display was always visible. Order of the sessions was counterbalanced among observers.

An analysis of variance of detections for the two sessions (Fig. 1, D-1 and D-2) showed significant decrements with time and significant differences in over-all performance, but no significant order effects or other interactions. The decrements are typical of vigilance experiments (*1*), and the insignificant interactions indicate that introducing illumination-responses reduced the absolute number of detections but left the shape of the curve intact. The illumination-response curve (R-2) followed the detection curve (D-2). The latter result

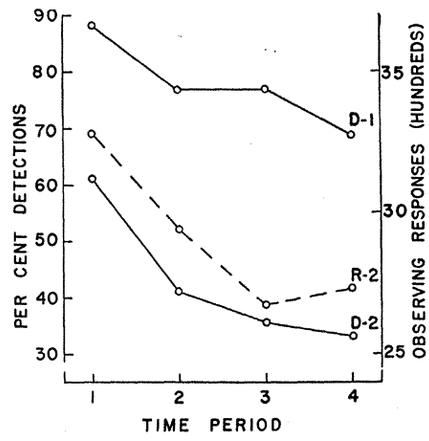

Fig. 1. Signal-detections and illumination-responses during four successive 23-minute portions (time periods) of continuous 92-minute vigils. D-1, signal-detections in session with externally illuminated display; D-2, signal-detections in session with display illuminated by observer's illumination-responses; R-2, illumination-responses (ordinate scale at right) during D-2 session.

Table 1. Spearman rank-correlation coefficients. D-1, D-2, and R-2 are defined in the legend to Fig. 1. Correlations in italics are split-half reliabilities (periods 1 + 3 versus 2 + 4).

	D-1	D-2	R-2
D-1	*.49**	.67†	.21
D-2		*.69†*	.54*
R-2			*.90†*

* Significant at the .05 level. † Significant at the .01 level.

confirms Holland's (see *3*, Fig. 9), indicating that we had succeeded in reproducing his conditions.

Using each observer's over-all performance in each session, we then performed the correlational analysis summarized in Table 1. The correlations show, first, that each measure was reasonably reliable (*9*). Second, the significant correlation between D-1 and D-2 may be interpreted as being due to the common "vigilance" factor in signal-detections. Third, the significant correlation between detections in the illumination-response session (D-2) and illumination-responses (R-2) also implies a common factor. The basic question is whether or not the latter factor is the same "vigilance" factor common to detections.

The answer lies in the correlation between detections in the session without illumination-responses (D-1) (which are governed in part by the "vigilance" factor) and the illumination-responses (R-2). The insignificant Spearman rank-correlation of 0.21 suggests that illumination-responses are not governed by a "vigilance" factor. A Kendall (*10*) partial-rank correlation, r, is appropriate here to remove spurious correlations between D-1 and R-2 due to their common correlation with D-2. We found

$$r_{(D\text{-}1)(R\text{-}2).\,(D\text{-}2)} = -.09,$$

indicating the complete absence of a positive correlation and, by implication, of a "vigilance" factor in illumination-responses. Thus, except for the artifact introduced in Holland's procedure by making detections impossible unless signals and illumination-responses occur simultaneously, we cannot consider that illumination-responses govern detections, at least not detections as related to vigilance. On the other hand, Holland's results support the opposite causal relation, that detections control the rate of emitting illumination-responses.

Holland's work was inspired by the results of research on the relationship between schedules of reinforcement and operant behavior (see *4*), and it is appropriate to phrase our conclusions in the same terms. Presently available evidence permits the assumption that detections (not signals) are reinforcements. But detections are "scheduled" by the observer rather than by the experimenter, and the major problem in research on vigilance is how and why the observer produces these schedules. It is irrelevant for this problem (though certainly interesting) that the schedules, once produced, can control an operant like the illumination-response. The analogy with operant behavior is to the question of how an experimenter decides on particular schedules of reinforcement, because the observer is in the role of an experimenter arranging a schedule of detections.

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References and Notes

1. H. J. Jerison, "The Empirical Model for Human Vigilance," *USAF WADC TR 58-526* (Wright-Patterson AFB, Ohio, 1959).
2. J. G. Holland, *Science* **125**, 348 (1957).
3. ———, *ibid.* **128**, 61 (1958).
4. B. F. Skinner, *Am. Scientist* **45**, 343 (1957).
5. This research was supported by the U.S. Air Force under contract No. AF 33(616)-6095, monitored by the Behavioral Sciences Laboratory, Wright Air Development Division, Wright-Patterson Air Force Base, Ohio. The assistance of James M. Campbell in apparatus design and construction and Ruth Cowperthwaite in data collection and analysis is gratefully acknowledged.
6. C. H. Baker, *Science* **132**, 674 (1960).
7. D. N. Buckner, A. Harabedian, J. J. McGrath, *Human Factor Problems in Anti-submarine Warfare, Technical Report 2: A Study of Individual Differences in Vigilance Performance* (Human Factors Research, Inc., Los Angeles, 1960).
8. N. H. Mackworth, "Researches on the measurement of human performance," *Med. Research Council Rept. No. 268* (H.M.S.O., London, 1950).
9. The apparently low reliability of the D-1 measure is attributable to very high detection rates by all observers early in that session. This reduced variability for part of a session would have a greater effect on split-half than on test-retest correlations. The true reliability is probably at least as high as the correlation between D-1 and D-2.
10. M. G. Kendall, *Rank Correlation Methods* (Hafner, New York, ed. 2, 1955).

2 December 1960

Ion Uptake by Living Plant Roots

Abstract. By taking daily autoradiographs of a uniformly labeled soil in which plants are growing, patterns of actual ion uptake from the soil can be established. This technique can be used to study such influences on ion uptake as that of plant species ion diffusion, moisture and temperature stresses, and different physical, chemical, and biological properties of the soil.

Some investigators (*1*) have suggested that because of ion uptake the nutrient level is low in the soil in the vicinity of the root and a gradient exists out from the root into the surrounding soil. The exact nature of this gradient has not been established. Usually the average level of a nutrient in the soil after cropping, in conjunction with the uptake by the plant, has been used as a measure of the absorption pattern. The following technique was devised to study the actual pattern of ion uptake.

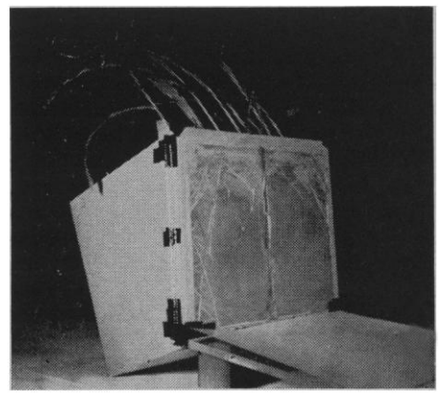

Fig. 1. Corn roots growing in uniformly labeled soil in a box designed to permit frequent taking of autoradiographs.

Corn was grown in the specially designed box shown in Fig. 1. The front side of the plywood box was sloped so that the corn roots were forced to follow this open face. A 2-mil polyethylene film was stretched across the open side, confining the soil. A ⅜-inch Plexiglas door, hinged at the bottom, could be moved up to make contact with the plastic film, or lowered, as pictured in Fig. 1, to secure the soil. A ⅛-inch layer of soil, uniformly labeled with rubidium-86, was spread next to the polyethylene film. The remainder of the box was filled with unlabeled soil. The uniformly labeled soil was prepared by stirring 100 ml of solution, containing approximately 150 μc of rubidium-86, with 250 g of air-dry 50-mesh sieved soil. After air-drying, the labeled soil was ground and mixed with a mortar and pestle.

Germinated corn was planted 1½ inches back from the polyethylene film. When the box was placed in the greenhouse, the open side was shielded from the sunlight with aluminum foil. A 1-inch layer of pearlite was placed on the top of the soil to prevent evaporation, and the soil was kept at a moisture content of approximately 20 percent.

Roots are shown growing in the labeled soil against the plastic film in Fig. 1. Autoradiographs were obtained by taking the box into a photographic darkroom and there blocking it up so that the open side would be vertical (*2*). Blocking was necessary to avoid disturbing the labeled soil. In total darkness a 10- by 12-inch no-screen x-ray film was placed on the Plexiglas door as shown in Fig. 1. The door was tightly closed, pressing the x-ray film against the polyethylene film. The film was exposed for 1 hour on the first day with an approximate 10-minute increase in exposure time daily to allow for