Under Nembutal anesthesia 30 Long-Evans male rats had bilateral implants of bipolar plastic products (No. MS-303, 0.025 cm in diameter) cranial plugs placed into the frontal cortical region ($N = 25$) (coordinates 2.0 mm anterior to Bregma, 2.5 mm lateral, and at the surface of the brain) and into the caudate nucleus ($N = 5$) (coordinates 0.5 mm anterior to Bregma, 2.5 mm lateral, and 5 mm vertical); measurements were taken from a level skull. The electrode assembly was fixed to the skull with acrylic cement. Another eleven rats did not undergo any surgery. At least 2 weeks after recovery from surgery, all animals received the initial injection of morphine (30 mg/kg) followed either 5 minutes later ($N = 7$) or 180 minutes later ($N = 8$) by bilateral frontal area stimulation (eight 5-second trains of biphasic pulses with 10 seconds between trains at an intensity of 1.5 ma, 100 hertz, 1 msec duration), or, 5 minutes later, by bilateral caudate stimulation ($N = 5$) (eight 5-second trains of biphasic pulses with 10 seconds between trains at an intensity of 500 μa, 30 hertz, 1 msec duration), or no stimulation for the frontal implanted ($N = 10$) and the nonoperated ($N = 11$) groups. Electrical stimulation was delivered via two Nuclear-Chicago constant-current stimulators. Electrographic activity was recorded from the frontal cortical region or caudate electrodes immediately after stimulation offset. At the stimulation levels employed, no seizure afterdischarges or other electroencephalographic abnormalities were recorded. Forty-eight hours later all rats received an injection of morphine (15 mg/kg) followed 30 minutes later by the test for analgesia (*8*). The mean shock intensities for the flinch, jump, and jump and squeal thresholds, and criterion for all the groups are shown in Table 2.

The data were analyzed with a one-way analysis of variance which indicated that there were significant differences among the groups only for the jump and squeal measure ($F = 3.1$, d.f. = 4/36, $P < .05$). A Duncan Multiple Range Test revealed that frontal cortical region stimulation applied 5 minutes but not 3 hours after the first morphine injection disrupted the development of tolerance as indicated by a significant increase in mean jump and squeal threshold relative to unoperated and operated controls ($P < .01$ and $P < .05$ respectively). The results of frontal cortical stimulation therefore suggest that the frontal cortical region and interconnected neuronal systems may play a role in the development of morphine tolerance. Caudate nucleus stimulation did not disrupt morphine tolerance. However, the failure of caudate nucleus stimulation to disrupt morphine tolerance could have been due to inappropriate selection of frequency or intensity parameters, or both, or due to the strong possibility that different neuronal regions mediate different kinds of learning experiences (*3*).

In conclusion, the data from both the ECS and discrete brain stimulation experiments provide additional support for a possible parallel between conventional learning and tolerance to drugs.

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References and Notes

1. G. Ungar and L. Galvan, *Proc. Soc. Exp. Biol. Med.* **130**, 287 (1969); H. O. J. Collier, *Endeavour* **31**, 123 (1972).
2. B. M. Cox, in *Agonist and Antagonist Actions of Narcotic Analgesic Drugs*, H. W. Kosterlitz, H. O. J. Collier, J. E. Villarreal, Eds. (University Park Press, Baltimore, 1973), pp. 217–231; L. R. Squire and S. H. Barondes, *Proc. Natl. Acad. Sci. U.S.A.* **69**, 1416 (1972); ——, in *Macromolecules and Behavior*, J. Gaito, Ed. (Appleton-Century-Crofts, New York, 1972), pp. 61–81; L. L. Uphouse, J. W. MacInnes, K. Schlesinger, *Behav. Genet.* **4**, 29 (1974).
3. R. P. Kesner and M. S. Wilburn, *Behav. Biol.* **10**, 259 (1974); J. L. McGaugh and M. J. Herz, *Memory Consolidation* (Albion, San Francisco, 1972); P. E. Gold, S. F. Zornetzer, J. L. McGaugh, in *Advances in Psychobiology*, G. Newton and A. Riesen, Eds. (Wiley, New York, 1974), vol. 2, pp. 193–224.
4. J. Cochin and C. Kornetsky, *J. Pharmacol. Exp. Ther.* **145**, 1 (1964); C. Kornetsky and G. Bain, *Science* **162**, 1011 (1968).
5. The behavioral procedure is similar but not identical to that described by K. A. Bonnet and K. E. Peterson, *Pharmacol. Biochem. Behav.* **3**, 47 (1975).
6. S. H. Snyder, *Neurosci. Res. Program Bull.* 13 Suppl., 1 (1975).
7. M. J. Herz and H. V. S. Peeke, *Brain Res.* **33**, 519 (1971); J. L. McGaugh, S. F. Zornetzer, P. E. Gold, P. W. Landfield, *Q. Rev. Biophys.* **5**, 163 (1972); E. J. Wyers, H. V. S. Peeke, J. F. Williston, M. J. Herz, *Exp. Neurol.* **22**, 350 (1968).
8. At the termination of the experiments all rats were anesthetized with Nembutal and perfused pericardially with saline and formal-saline. The brains were cut at 50-μ sections through the electrode tracks and were stained with cresylviolet. Results are presented only for histologically verified placements in frontal cortex and caudate nucleus.
9. Supported by NIH Biomedical Sciences support grant RR-07092 and PHS grant No. MM25706-01. We thank R. Berman for critical reading of the manuscript.

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Perceptual Analysis of Moving Patterns

Abstract. Configurations of moving points are often perceptually analyzed into relative and common vectors that are different from the actual motions. If a movement configuration is abruptly replaced by a test point whose objective velocity continues the apparent (but illusory) course of one of the original points, observers perceive that course as uninterrupted and colinear. This finding provides a quantitative measure of the vector extraction phenomenon and was used to show that neither of the two current models adequately fits that phenomenon.

Johansson and his colleagues (*1, 2*) have shown that, in configurations of moving elements that share common motion components, one *common* vector becomes the frame of reference for residual component motions (Fig. 1). The rows of spots labeled *A* and *C* move from left to right, while *B* moves between them along a diagonal path. If the horizontal component of *B*'s motion equals that of *A* and *C*, and if this configuration is viewed against a homogeneous black background, the diagonal motion of *B* becomes almost impossible to discern (*1*). Instead, *B* appears to move vertically between *A* and *C*, while the whole system of spots, *ABC*, may also be perceived as moving to the right.

The phenomenon of perceptual vector extraction is not merely a laboratory curiosity. It has been taken as an example of the visual system's sensitivity to higher-order variables of stimulation (*3*), as the basis for much of the observer's information about his movements in his environment (*2*), and as an important component of tridimensional space perception (*2, 3*). To Johansson, the process is a direct vector analysis, performed automatically by the perceptual system on the entire visual field. Stoper (*4*) has suggested, however, that the phenomenon has a peripheral explanation, that it occurs because the eye pursues the common vector, and that what we perceive is simply the residual movement that the pursued stimulus then projects to the retina of the eye.

We now describe a quantitative measure of the phenomenon of vector extraction that calls into question the adequacy of both earlier explanations. In Fig. 2, the pattern of moving elements is the same as that in Fig. 1, until some time t_1. At that time, rows *A* and *C* are deleted and, simultaneously, element *B* changes its path to the vertical ($\theta = 90°$). If *B*'s motion, before t_1, is really perceived as vertical (and if the effect of the moving framework ceases when *A* and *C* are deleted), then *B*'s motion should appear to be continuous and colinear between movements *ii* and *iii*, even though that is not the physical situation.

Four male and four female paid volunteer subjects constituted the experimental group. Naive as to the stimulus conditions and the hypothesis under examination, all subjects reported some degree of perceptual vector extraction while viewing the standard stimulus (Fig. 2) in a preliminary session.

Stimuli were generated by a small computer (Digital Equipment Corporation PDP-8e) and displayed on an oscilloscope (Tektronix RM503) (*5*). Subjects viewed the oscilloscope screen from a distance of 50 cm through a visor, which reduced head movements and obscured any stray light that might enter the darkened experimental room. A red filter (Corning No. 244) mounted between the screen and the subject attenuated the persistent glow of the oscilloscope phosphor.

Subjects sat before a response panel mounted vertically at chest height. Keys designated "Ready" (to begin a trial), "Match" (perceived colinear motion), and "Mismatch" (perceived change in direction at t_1) were located above an adjustable potentiometer whose output (converted to a 12-bit digital code) served as input to the program (*6*) that generated the display. The potentiometer was adjusted so that the direction of motion *iii* matched that of motion *ii*, after which the absolute reference of the potentiometer was randomly changed.

When the subject initiated a trial, a single stationary spot, *D*, appeared. He was instructed to look directly at this spot and to signal the computer to begin the standard motion: Initially, seven dots were shown to the left of *D* (Fig. 2). Three dots, labeled *C* in Fig. 2 (*7*), were colinear with *D*. The spots labeled *A* were always directly above *C*. Both *A* and *C* moved at 0.833° visual angle per second on the paths shown. Point *B* initially coincided with the center dot in *C*. During the standard motion, *B* moved along a path at 45° with respect to *C* at 1.18° visual angle per second (horizontal and vertical components both equal to 0.833°/sec). Spot *B* reached a point midway between *A* and *C* 3.24 seconds after the standard motion started. At this time, all lights but *B* and *D* were deleted, and *B* assumed the comparison velocity, *iii*; the vertical component remained unchanged, while the horizontal component reflected the setting of the adjustable potentiometer (*8*).

After each trial, the observer pressed either the "Match" or the "Mismatch" key and, in the latter case, readjusted the potentiometer before the next trial (*9*). The observer received no feedback concerning correctness. Experimental sessions began with instructions to the subject and as many practice trials as were needed to achieve two subjective matches; an additional 25 matches were then made. A 3-minute rest followed the 15th match.

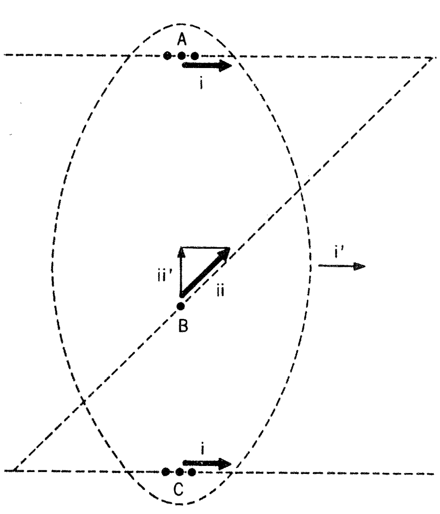

Fig. 1. Johansson phenomenon: real motions are shown by arrows *i* and *ii*; apparent motions, by vectors *i'* and *ii'*.

The comparison angle formed with the horizontal by dot *B* and judged to be colinear with the standard (45°) path was measured for each subject. The constant error was significant for each subject ($P < .001$), and the mean across subjects is significantly different from 45° ($\bar{X} = 69.8°$, S.D. = 11.32, $t \doteq 5.97$, d.f. = 7, $P < .001$).

Subjects' introspections and their colinearity adjustments confirmed the existence of a phenomenon similar to Johansson's vector analysis. The possibility that the results are an artifact of the measurement method was ruled out by a control experiment with eight naive paid observers in which conditions were identical to those described previously, with the exceptions that (i) a different oscilloscope was used (Tektronix 5103N with a rapid-decay phosphor), and the displays were approximately equated for brightness; and (ii) only spots *B* and *D* were presented during the standard motion. Each subject made ten matches. Means of the groups in the experimental and control conditions are significantly different ($t = 6.00$, d.f. = 14, $P < .005$). The mean for the control group was not significantly different from 45°. We conclude, therefore, that (i) the Johansson effect obtained in the experimental group results from the presence of the reference elements *A* and *C* and is not an artifact of the measurement method, and (ii) our procedure is a psychophysical measure of movement organization.

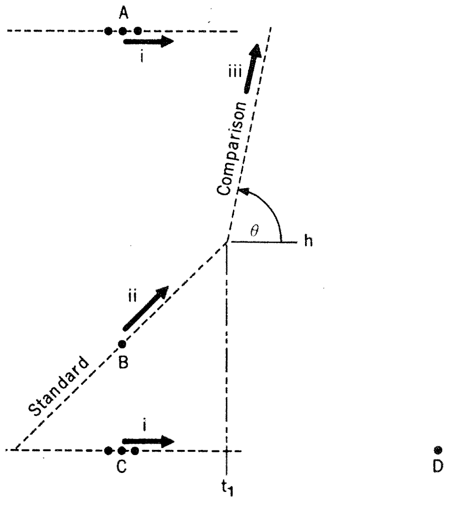

Fig. 2. Standard motions of *A*, *B*, and *C* are shown by *i* and *ii*; *D* was stationary. The comparison motion of *B*, labeled *iii*, was set by the subject so that its direction, θ, appeared equal to *ii*.

Because the Johansson effect was obtained under strict fixation instructions, we must consider whether pursuit movements, executed against instructions, are likely to be responsible for these results. The first experimental subject, still naive as to the experiment's purpose, made another 25 matches while her eye movements were monitored by a Whittaker eye view monitor system (*10*); she showed a significant Johansson effect (mean perceived direction = 76.35°, $t = 34.75$, d.f. = 24, $P < .001$) and no discernible pursuit movements. Subsequently, six new judgments were made with a larger display, in which spot *B* reached the midpoint 6 seconds after the standard motion started, so that the horizontal and vertical excursions were now 5° instead of 2.7°. The subject's mean perceived direction was now 77.36° ($t = 9.1$, d.f. = 5, $P < .005$). Small saccades were now evident, with a mean of 0.8° and a standard deviation of 0.32°. With the possible exception of one presentation, which contained two movements of 1-second duration each (but in opposite directions), no discernible pursuit movements were displayed, nor did an overall trend in the direction of the display motion appear: least-squares lines fitted to plots of horizontal deviation from the fixation point over time gave an average slope of −.10, S.D. = 0.28.

We should not, of course, overgeneralize this point. Pursuit movements may, when they occur, contribute to the Johansson effect by canceling the stimulus motion in the retinal image, just as Stoper proposed; the procedure that we have developed could then serve to measure that contribution. We have no way of knowing the degree to which the other subjects in the main body of our experiment made pursuit movements despite the fixation instructions and the fixation point. This auxilliary experiment shows that the Johansson effect cannot be explained solely as the cancellation of the stimulus motion by effects of pursuit eye movements.

A second substantive finding in these data is that, because of the stationary point *D*, there is no common vector greater than zero. Thus the results do not support an explanation of the Johansson effect in terms of an automatic vector extraction applied over the entire field of view. Perhaps the vector-extraction model must be phrased in more local terms (for example, beyond some distance, the points do not affect each other), or perhaps it must take the observer's intention into account.

Both findings call for quantitative measurement under a wider range of conditions before we can essay a more adequate theory. Our method should prove valuable for that purpose and for the more general problem of determining the stimulus and task factors responsible for the organization of motion perception.

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References and Notes

1. G. Johansson, *Configurations in Event Perception* (Almqvist and Wicksell, Uppsala, 1950).
2. ——, *Visual Motion Perception* (Psychology Laboratory Report, University of Uppsala, Uppsala, 1971).
3. G. Johansson, in *Perception: Essays in Honor of James J. Gibson*, R. MacLeod and H. Pick, Eds. (Cornell, Ithaca, 1974), p. 135.
4. A. Stoper, *Percept. Psychophys.* **13**, 201 (1973).
5. Display timing was controlled by a crystal clock (DEC Dk8-EC). A point-plot display unit (DEC VC8E) linked the CPU to the oscilloscope. The display was presented 850 times each second. Between any two successive display cycles, a point could move 0.012° of visual angle. The speed of spot motion was controlled by varying the number of display cycles between displacements.
6. An assembly language program was developed by P.F. to compute and control the display of moving dot patterns. The package provides relatively high speed and absolute control of presentation rate.
7. Three dots were used here, as they were more distinctive in peripheral vision than a single dot would have been. The horizontal extent of the line formed was 0.34° of visual angle.
8. The horizontal velocity component of the comparison stimulus was within the range of ± 9.57° visual angle per second.
9. The subject could not control the motion of *B* during its presentation. Except after a match was reported, the same motion would result if the potentiometer were left unchanged.
10. This instrument is a television analog computer system that calculates the direction of gaze by comparing the position of the center of the pupil of the left eye with the center of a corneal reflection in that eye. Accuracy is typically well within 1.5° of visual angle, and the device is relatively free from error introduced by small head movements. The working precision varies with subject and configuration; in this experiment, changes in horizontal eye direction of 0.36° could always be detected. An eye patch occluded the right eye. The stimulus field was no longer in complete darkness (as it was in the first experiment). Instead, the infrared illuminator of the eye movement monitor introduced a dim visible haze through which the stimulus dots appeared to move, which may have caused the slight decrease in that subject's Johansson effect (this decrease was not significant: $t = 1.14$, d.f. $= 48$, $P > .10$).
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Deep-Sea Macroplanktonic Sea Cucumbers: Suspended Sediment Feeders Captured from Deep Submergence Vehicle

Abstract. *Observations in situ confirm the swimming and feeding behavior in previously unreported dense assemblages of the holothurian* Peniagone diaphana, *at a depth of 2000 meters, off southern California. Proximate analysis of captured specimens indicates that this organism may represent a numerically significant, but low organic content member of many near-bottom deep-sea communities.*

Ever since Théel defined the deep-sea holothurian order Elasipoda (*1*), the bizarre variations in body form of these unusual animals have been of great interest to zoologists who study morphology (*1*, *2*). Indeed, one can hardly invoke a less appropriate term than "sea cucumber" to describe the translucent, vertically oriented, free-swimming forms (Fig. 1), which we saw in all directions from a deep sea submersible cruising near the sea floor, 2000 m deep off San Clemente Island. The real significance of being surrounded by living hordes of an organism known previously from only a handful of preserved specimens (*3*), is that we now have a record for the existence of a substantial population (*4*) of relatively large deep-sea organisms, living in close association with the sea floor, yet scarcely considered (*5*) in the various models of energy exchange proposed for the deep ocean (*6*). This oversight is undoubtedly due to the fact that deep-sea near-bottom communities (within 200 m of the bottom) have not been routinely or effectively sampled.

A series of dives in Deep Submer-

Fig. 1. A photograph in situ of *Peniagone diaphana* drifting above the sea floor at a depth of approximately 2000 m.