tained with simultaneous foveal presentation.

The orderly subtractive data are obtained despite wide fluctuations in the absolute levels of the times obtained with different intervals. The mean time to respond to a physically identical pair when the two stimuli are simultaneous is nearly 900 msec. Of course, this must include the time for an eye movement from the first stimulus at the left side to the second stimulus at the right side of the tape. The time for the eye movement is removed when there is a delay period. Thus the delay conditions have mean times for physical identity which are close to half as long as that for the zero condition. There is also a tendency for all times to increase between 0.5- and 1.5-second delays. This increase in the absolute level of the times presumably reflects the increasing temporal uncertainty when subjects are required to wait for the second stimulus. This is a frequent finding in studies of reaction time (*5*).

The results described in the preceding paragraph are borne out by statistical analyses. An analysis of variance was performed on the data presented in Table 1. The analysis showed that the effects of interval (0, ½, 1, and 1½ seconds) and of type of stimulus pair (physical identity, name identity, and different) were both significant $P < .01$. A linear trend analysis was run on the interaction between intervals and type of pair. This interaction is the curve displayed in Fig. 1. The results showed a significant linear interaction between types and interval ($.025 > P > .01$).

Not all subjects showed the orderly linear relationship reflected in the means. This may be owing to the relatively little data obtained from individual subjects and the local effects of order which were different for different subjects. There is, however, considerable uniformity, since out of 24 comparisons of name identity minus physical identity at zero and 0.5 second, 22 show a positive sign and only one shows a negative sign. A similar comparison of 12 subtractions of name minus physical identity at 1 second gives nine positive and three negative, and at 1.5 second, seven are positive and five negative.

It seems reasonable to conclude from the functions shown in Fig. 1 that the visual information from the first letter shows a significant decay over time. The statistical analysis indicates that under these conditions the advantage of physical identity is lost after 1 to 1.5 seconds' delay.

Two objections might be raised to this conclusion. In the name identity condition the second letter is always lower case, and it could be that lower case letters are processed more slowly. This suggestion seems unlikely in view of the decay found over time. Moreover, there is no tendency for different responses which involve a lower case letter to be slower than those involving capitals only. The second objection concerns the fact that the first letter is present in the periphery of the visual field during the whole trial. It could be that subjects look at the first letter for a variable time as the interval increases. Subsequent studies have employed intervals which varied randomly over trials and conditions in which the first letter does not remain present. They have generally confirmed the findings presented here. It should be possible, however, to obtain much more accurate determinations of the decay functions than presented in this study.

The study reported in this paper differs considerably in methodology from previous reports concerning decaying visual information. Two differences appear to be crucial. All previous studies have used bright tachistoscopic flashes and have presented large amounts of information which cannot be encoded immediately. This study used reading light and only a single letter. The low error rate suggests that the subject has ample time to encode the letter. In view of these differences it is somewhat surprising that the decay rate obtained is so high and so closely resembles that in previous studies (*1*).

We believe that this rapid decay occurs only when the subject does not attempt to preserve the visual information from the first letter. In this experiment, the subject was given little or no incentive for preserving the visual information. He never knew whether he would receive a capital or small letter as the second stimulus. Thus, as the subjects report, the major way of preserving information seemed to be by way of verbalizing the letter and retaining the name during the interval. This should not be taken to mean that subjects would be unable to preserve the visual information of the first letter if, in fact, they desired to do so.

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## Trans-2-Hexenal: Mating Stimulant for Polyphemus Moths

Abstract. *The volatile compound from oak leaves which stimulates the female polyphemus moth to release her sex pheromone has been isolated and identified as* trans-2-hexenal. *Although leaves of other food plants contain* trans-*2-hexenal, they also release masking odors which block the activity of the hexenal.*

Polyphemus moths (*Antheraea polyphemus*) will not mate in the laboratory unless a volatile substance found in red-oak leaves is present. When the female receives the emanation via her antennae, she releases a sex pheromone, which attracts the male (*1*). Vacuum distillation, either of aqueous suspensions of frozen leaves or of fresh leaves, followed by preparative gas chromatography, has led to the isolation of the volatile oak-factor and its identification as *trans*-2-hexenal.

Vacuum distillation of freshly ground oak leaves under a reduced pressure of 70 to 80 mm-Hg produced a biologically active distillate (distilling temperature 40° to 46°C) which was collected in a bath of dry ice and acetone. When analyzed by gas chromatography (Barber-Colman; 1.8-m by 3.5-mm glass column packed with Poly-pak-2, at a column temperature of 140°C), this fraction contained at least four components with short retention times. The three major components were isolated by preparative gas chromatography on a glass column (2.4 m by 14.5 mm) packed with Poly-prep-pak-2 (F and M Scientific) at a column temperature of 212°C with nitrogen used as the carrier gas (300 ml/minute). Only one compound (retention time 13 minutes) provoked mating.

The characterization of this compound was greatly simplified by the finding that an aqueous extract of oak leaves could be inactivated by selective precipitation of aldehydes with Dimedone (*2*). Commercially available $C_2$ to $C_6$ straight-chain aldehydes known to be present in oak leaves (*3*) were then tested, both undiluted and in 0.5 percent aqueous solutions (*4, 5*). Only 0.5 percent aqueous solutions of hexanal and *trans*-2-hexanal provoked mating.

The isolated active component from the oak-leaf distillate was identified as *trans*-2-hexenal by co-chromatography with an authentic sample on a glass column (1.8 m by 3.5 mm) with Polypak-2 at column temperatures of either 104° or 147°C. Further comparison of this component with purified *trans*-2-hexenal (*6*) by mass spectrometry (*7*), by infrared and nuclear magnetic resonance spectroscopy (*7*), and by characterization of the 2,4-dinitrophenylhydrazine derivative (*2*) established its identity as *trans*-2-hexenal. The mass spectra of *trans*-2-hexenal and the unknown were identical with a parent ion having a mass-to-charge ratio of 98, a base peak with a mass-to-charge ratio of 41, and other prominent peaks with mass-to-charge ratios of 83 and 69.

The infrared spectrum showed characteristic maxima at 2700, 1680, and 1625 $\text{cm}^{-1}$, indicative of an $\alpha,\beta$-unsaturated aldehyde, and a maximum at 970 $\text{cm}^{-1}$, indicative of the *trans* configuration at the double bond (*8*). In the nuclear magnetic resonance spectrum, a doublet at a chemical shift of 9.6 parts per million also indicated an aldehydic proton (*9*). Thin-layer chromatography on silica gel (Merck; chloroform solvent) of the 2,4-dinitrophenylhydrazone, melting point 149°C (uncorrected), gave an $R_F$ value (0.63) identical to that of the derivative of the pure *trans*-2-hexenal. There was no depression of melting point when the compounds were mixed.

The solubility properties of *trans*-2-hexenal appear not to correspond with the previously reported activity of polar extracts of oak leaves (*1*). The limited effective concentration range of $10^{-5}$ to 1 percent *trans*-2-hexenal [as determined in the standard bioassay (*1*), with 5 ml of an aqueous solution containing a filter-paper wick, 0.5 by 10 cm] provides the explanation. The 0.05 to 0.005 percent solutions were most effective, resulting in 50 to 75 percent mating, respectively; there was a progressively lower percentage of mating at both higher and lower concentrations. Previously it had been noted that aqueous extracts lost activity when concentrated by distillation but regained it upon dilution (*5*). The polar solvents evidently extracted a sufficient quantity of hexenal for activity, but the nonpolar extracts must have contained too high a concentration of *trans*-2-hexenal. After the compound was identified, gas chromatography confirmed that a petroleum ether extract of oak leaves contained *trans*-2-hexenal (*10*).

The basis of the hyperconcentration phenomenon remains obscure. The female moth is the one affected, since with concentrations of greater than 1 percent 2-hexenal, no "calling" (*11*) is observed; at lower concentrations, "calling" is more frequent than actual matings. The male's perception of the female's pheromone is not affected. Thus, the exposure to the vapors of pure *trans*-2-hexenal does not prevent males from mating with females whose antennae have been recently removed; such females, as previously shown, release their pheromone without other stimulation (*1*).

Although *trans*-2-hexenal is ubiquitous in green leaves (*3, 12*), leaves of other food plants of polyphemus do not provoke mating (*1*). Either oak leaves release more *trans*-2-hexenal than other food plants tested, or these other types of leaves also release masking odors. As judged by gas chromatography, vacuum distillates of oak, maple, birch, beech, and elm leaves contain roughly equivalent amounts (within a factor of two) of *trans*-2-hexenal per wet weight of leaves. This extractable amount is not necessarily equivalent to that released; thus in the biological assay a five- to tenfold increase in the amount of the other leaves does not produce mating.

All other leaves except elm block the action of both oak leaves and 0.05 percent *trans*-2-hexenal. Previous studies have shown that volatile substances such as Chanel 5 also block the action of the oak-leaf factor on the female moth (*4*). In both cases, this blocking action is competitive since it may be overcome by increasing the quantity of oak leaves or the volume of the hexenal solution.

The vapors of aqueous solutions (0.5 percent) of purified 2,4-hexadienal, 2,4-hexadienol, heptanal, cycloheptanone, and octanal were inactive. Hexanal and *cis*-3-hexenol (Aldrich; purified by gas chromatography) were occasionally active when tested at the 0.5 percent level. The activity of *cis*-3-hexenol can be accounted for in terms of its oxidation to *trans*-2-hexenal on exposure to air (*13*). The occasional response to the vapors of hexanal implies that the antennal receptors are not wholly specific for *trans*-2-hexenal.

*Trans*-2-hexenal is not new in insect communication systems. It has been identified as the component of mulberry leaves which attracts older *Bombyx mori* larvae (younger larvae are attracted by *cis*-3-hexenol) (*14*). *Trans*-2-hexenal is also found in defensive secretions of some cockroaches and hemipterans, and one species of ant (*15*). Most of these secretions are mixtures of this aldehyde with other unsaturated aldehydes, but the secretion of cockroaches of the genus *Eurycotis* contains only *trans*-2-hexenal and gluconic acid (*16*). Therefore, it is not surprising to find that the emanation from *Eurycotis biolleyi* (*17*) can provoke the mating of polyphemus moths.

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6. The commercial *trans*-2-hexenal (Aldrich) was purified by preparative gas chromatography, with the same conditions as outlined for the oak distillate.
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## Cognitive Capacity of Very Young Children

Abstract. *Children between 2 years, 6 months old and 3 years, 2 months old correctly discriminate the relative number of objects in two rows; between 3 years, 2 months and 4 years, 6 months they indicate a longer row with fewer objects to have "more"; after 4 years, 6 months they again discriminate correctly. The discriminative ability of the younger children shows that the logical capacity for cognitive operations exists earlier than previously acknowledged.*

J. Piaget has investigated the mistakes which children make in solving simple problems (*1*). In the most often quoted of Piaget's experiments, a child sees two identical arrays of material and is asked if he, in fact, thinks they are "the same." For example, a child of four characteristically replies that the two identical rows of four pellets in Fig. 1a are, in fact, "the same." The experimenter then adds or subtracts some material in one of the arrays and changes its shape at the same time. He again asks the child if both arrays have the same amount of material, or if one has "more." If the array is like the one in Fig. 1b, the same child reports incorrectly that there are now "more" in the upper row. However, a child of 5 correctly indicates that it is the array with the added material which has "more."

Various experimental techniques have been used to isolate the ages at which children develop the ability to ignore particular kinds of changes and to recognize when material is "conserved" (that is, not perceived as modified in quantity), in spite of those apparent changes. The development of the different kinds of quantity conservations is interpreted by Piaget as a behavioral reflection of the development of general cognitive capacities. For example, the 4-year-old's failure to conserve quantity in the above pellet experiment indicates that he does not have the cognitive capacity to "reverse" situations; hence, he cannot transform Fig. 1b back to Fig. 1a and then recall which particular row had the two pellets added to it. He instead responds to the momentary "appearance" of the two rows in Fig. 1b and incorrectly reports that the longer row has "more."

All of the well-known experiments on the conservation of quantity have ignored children below the age of 4. The exclusion of younger children has appeared rational because 4-year-old children do not have quantity conservation. If a 4-year-old does not have conservation, why should we expect an even younger child to exhibit it? Although this argument was reasonable, it was also misleading. The present study of over 200 children shows that under 3 years 2 months (3-2), children exhibit a form of quantity conservation; they lose it as they get older and do not exhibit it again until they are about 4 years 6 months (4-6).

Seven age groups of children from 2-4 to 4-7 were tested in individual sessions with two experiments involving quantity judgments. Each experiment used two pairs of rows like those shown in Fig. 1, a and b. One of the experimental sequences for each child had clay pellets while the other had M & M candies (candy-coated chocolate pellets). In each experimental sequence the child was first presented with adjacent rows of four, as in 1a, and he was asked if they were the "same." The experimenter then modified the arrays into a situation like 1b, in which a short row of six is adjacent to a longer row of four. In the experiment with clay pellets he was then asked which row had "more." In the experiment with M & M's the responses to situation 1b were nonverbal: instead of asking the child to state a quantity judgment, the experimenter asked him to "take the row you want to eat, and eat all the M & M's in that row." The order in which the M & M experiment and clay experiment were presented was balanced for each age group, as was the orientation of the arrays on the table in front of the child (*2*). Each session took about 10 minutes. The experimenter wrote down the response of the subject, and a tape recording was taken for subsequent analysis.

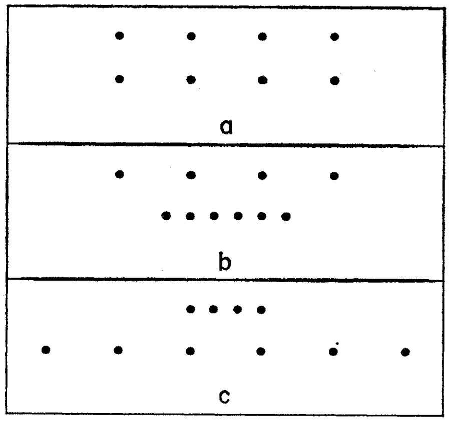

Fig. 1. The length of the rows in (a) was 7 inches (18 cm) for M & M's and 8 inches (20 cm) for clay pellets; in (b) 7 and 3 inches (18 and 8 cm) for M & M's and 8 and 5 inches (20 and 13 cm) for clay pellets. There was a 1⅓-inch (3-cm) space between each of the four clay pellets and a 2-inch (5-cm) space between each of the four M & M's. The clay pellets were ½ inch (1.3 cm) in diameter. The M & M candies were all of the same color.

The valid responses (*3*) are summarized by age in Fig. 2; the ordinate represents the proportion of success in choosing or naming the row which, in fact, had more (that is, the proportion of "conserving" responses) and the abscissa represents increasing age. Two bar graphs are presented, one for choosing which row of clay pellets had "more," (Fig. 2a) and one for taking a row of M & M's (Fig. 2b). Both experiments show a decrease in conserving responses by age, which is at a minimum in the group between 3-8 and 3-11. Thus, as the children get older than 2-6, they get worse, rather than better, at quantity conservation. Even more striking is the fact that the 23 youngest children (under 2-8) show extremely high numbers of conserving responses—100 percent of verbal responses on the quantity of clay pellets and 81 percent for taking rows of M & M's. The decrease with age is strongly significant for the verbal judgments ($P < .001$ by chi-square comparing 2-4 to 2-7 and 4-0 to 4-3 ages for verbal judgments) and nonsignificant for responses to M & M's. At 4-6, the children again show conservation for both kinds of quantity judgment (significance of increase in conservation of clay pellets between 4-0 to 4-3 and 4-4 to 4-7 = $P < .01$;