in vivo energy status is maintained, optimal fixation is accomplished by freeze-blowing the brain.

W. DAVID LUST
JANET V. PASSONNEAU
National Institute of Neurological Diseases and Stroke, National Institutes of Health, Bethesda, Maryland 20014
RICHARD L. VEECH
National Institute of Mental Health, St. Elizabeths Hospital, Washington, D.C. 20032

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Objective Assessment of Hypnotically Induced Time Distortion

Abstract. *The objective precision of operant conditioning methodology validates the power of hypnosis to induce alterations in time perception. Personal tempo was systematically modified by instructions to trained hypnotic subjects, with significant behavioral effects observed on a variety of response rate measures.*

Time perception is one of the most important, although least studied, consequences of the socialization process. Infants and children, whose behavior is primarily under the control of biological and situational exigencies, must be taught to develop a temporal perspective in which the immediacy of the experienced reality of the present is constrained by the hypothetical constructs of past and future. Society thereby transforms idiosyncratic, impulsive, and potentially disruptive behavior into approved, predictable, controllable reactions through the time-bound mechanisms of responsibility, obligation, guilt, incentive, and delayed gratification (*1*). The social acceptability of such reactions often depends on their rate of emission as much as upon other qualitative aspects. Thus, we develop, in addition to a sense of temporal perspective, a time sense of personal tempo, which involves both the estimation of the rate at which events are (or should be) occurring and affective reactions to different rates of stimulus input (*2*).

The learned correspondence between our subjective time sense and objective clock time can be disrupted by the physiological and psychological changes that accompany some types of mental illness, emotional arousal, body temperature variations, and drug-induced reactions (*3*). However, it is possible to modify either temporal perspective or tempo within a controlled experimental paradigm by means of hypnosis. Our previous research demonstrates the marked changes in cognition, affect, and action that result when hypnotized subjects internalize the instruction to experience a sense of "expanded present" (*4*). However, the data used to document such changes in this and related studies (*5*) have been too subjective and gross. In the present study we attempted to alter personal tempo and measure the behavioral consequences with precise, objective techniques.

The experience of tempo was systematically varied (speeded up or slowed down) by time-distorting instructions administered to hypnotic subjects and controls. If effective, such a manipulation should generate asynchronicity between clock time and the subjective passage of time. This asynchronous responding was assessed by means of the objective precision of a specially designed operant conditioning and recording apparatus. As predicted, the operant behavior of these hypnotized subjects was significantly altered relative to their own normal baseline and also to that of subjects in two control conditions.

The volunteer subjects were 36 Stanford University undergraduates of both sexes, who were selected from among the high scorers on a modified version of the Harvard group scale of hypnotic susceptibility (*6*) administered in their introductory psychology class. They were each randomly assigned to one of three treatments: hypnosis, hypnotic role-playing, and waking nonhypnotized controls. Before the experiment, the hypnosis group underwent a 10-hour training program designed to teach them to relax deeply; to concentrate; to experience distortions in perception, memory, and causal attribution; and to induce autohypnosis. The other subjects received no prior training. During the experiment, the testing procedure was identical for all subjects; an experimenter who was unaware of the experimental treatment delivered the standardized instructions to the subject, who sat isolated in an acoustic chamber. A second experimenter induced a state of hypnotic relaxation in the hypnosis group and instructed the hypnotic role-playing subjects to try their best to simulate the reactions of hypnotic subjects, to behave as if they were really hypnotized throughout the study. The waking controls were told only to relax for a period of time equivalent to that given to subjects in the other two treatments.

Subjects were taught to press a telegraph key at different rates in order to illuminate various target lights in an array of ten colored lights. In the first of five 2-minute trials, a comfortable operant rate of responding was established, and it became obvious to the

Table 1. Tempo modification. Data are mean deviations in the rate from baseline performance.

Treatment	N	No feedback	Objective feedback	Combined
Hypnotized	12	.534	.233	.38*
Role players	12	.299	.004	.15†
Waking controls	12	.023	.043	.03
		$P < .025$	$P < .005$	$P < .001$

* $P < .01$ for comparison with role players; $P < .001$ for comparison with waking controls. † Comparison with waking controls not significant.

subject that the sequential onset and offset of the lights was controlled by response rate. The functional relationship between response rate and change in the light stimulus was determined by relay circuits in the apparatus and can be characterized as a "conjugate" schedule of reinforcement (*7*). This schedule creates a dynamic interplay between behavior and a selected environmental event—the stimulus event changing continually as response rate varies. Pressing the key at a faster or slower rate than that required to illuminate the target stimulus light turned on one of the other lights in the array. It was only by empirically determining the rate appropriate to reach a particular target and then by maintaining that rate consistently that a subject could satisfy the task demand, "to keep light X illuminated as long as possible."

Of the remaining four trials, the first and third were baseline and the second and fourth were experimental. On one baseline trial, each subject was instructed to keep the red light illuminated, which required three presses per second. On the other baseline trial a faster rate of six responses per second was required to maintain the illumination of a blue light. Interspersed between these baseline trials and the experimental trials were the instructions to modify personal tempo. After being told about the differences between clock and subjective time, all subjects were instructed to alter their perception of tempo, by experiencing time as slowing down ("so that a second will seem like a minute, and a minute will seem like an hour"), and also by experiencing time as speeding up. Between these two tempo modification instructions, subjects were told to normalize their experience of time. The order in which these two tempo instructions (slower and faster) were given to each subject was counterbalanced across conditions (and did not have a significant effect upon the task behavior). A cumulative recorder provided an ongoing display of the subject's response rate and indicated whether responding was on- or off-target. In addition, an event recorder and electronic timers indicated to the experimenter the sequence and duration of the stimulus light levels being activated by variations in rate of responding.

The reinforcer for maintaining a particular target light level is probably the sense of competence a subject feels in being able to satisfy the experimenter's demand to do so. Knowledge of being off-target should serve as a negative reinforcer and guide efforts to modify responding to achieve the positive consequences of on-target performance. Such performance depends primarily upon two variables: a stable, veridical sense of personal tempo and the environmental feedback necessary for monitoring the effects of different response rates. Our tempo instructions, in conjunction with hypnosis, were designed to alter the first of these, and variation in feedback was introduced to alter the second. Within our repeated-measurements factorial design, the array of lights remained functional during the experimental periods for half the subjects (objective feedback), and they were extinguished during the experimental periods for the other subjects in each of the three conditions (no feedback). Those in the no feedback condition had to rely entirely on their memory of the previously appropriate baseline rates that they were asked to reproduce in the experimental periods, while objective feedback subjects had direct access to the external information provided by the illuminated array.

Since the electronic relay circuits in the apparatus function on fixed, real-time parameters, a subject operating on a subjective time dimension not in synchrony with clock time would have difficulty satisfying the task demand of achieving and maintaining a particular state of the apparatus. The absence of feedback frees task behavior from reality demands, thereby generating considerable asynchronous responding. But off-target responding can result from either intentionally altering response rate (without changing time sense) or altering personal tempo and thus indirectly affecting response rate. Feedback serves as a reality monitor to create a conflict only in subjects motivated to change their response rate voluntarily while also being motivated to maintain the target light level. For those who have internalized an altered sense of tempo, there is not a conflict between two competing motivations but rather an inability to successfully perform the task because of their altered cognitive state. They should continue to respond asynchronously even in the presence of feedback; the intentional responders should resolve their conflict in the direction of the most salient reinforcer—being on-target.

Only the hypnotic subjects were reliably able to translate the verbal sug-

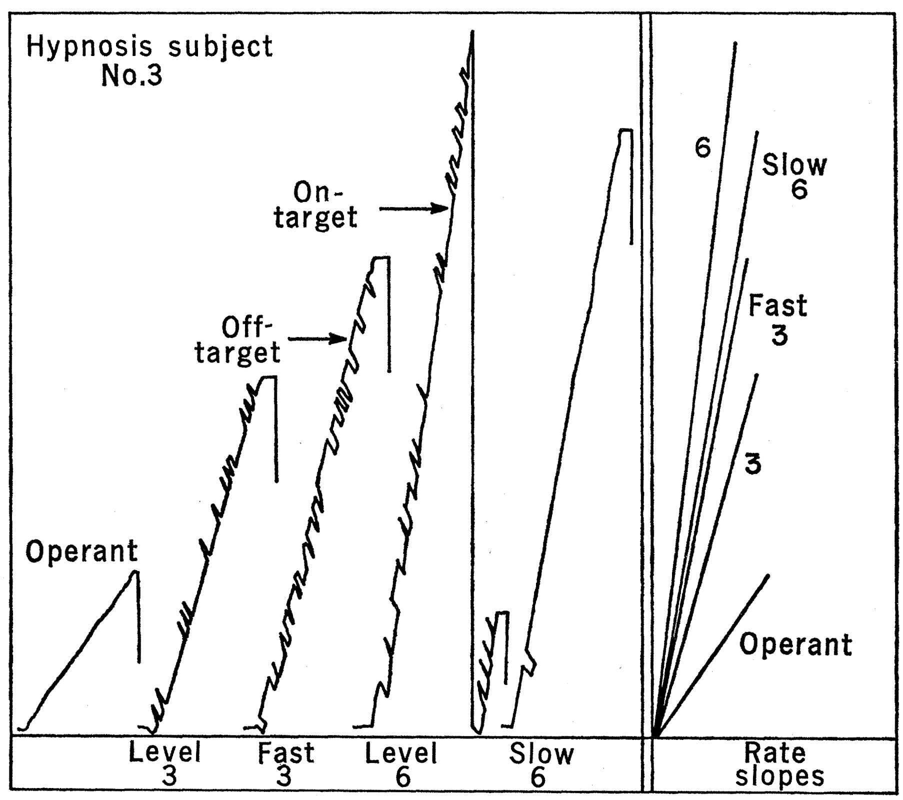

Fig. 1. Cumulative records of representative hypnotized subject during each of five 2-minute test periods. The slope of the curve indicates rate of responding. Superimposed on this curve are upward and downward deflections; downward deflections signify when response rate is synchronized with target stimulus rate (*on-target* arrow), and upward deflections indicate asynchrony (*off-target* arrow).

gestion of asynchronicity between clock time and personal time into behavioral "reality." This is shown in comparisons of mean rates of response, percentage of total time on- and off-target, mean deviation in individual response rates from baseline to experimental response levels, and in even the more subtle measures of variability—in displacement of the response distribution.

The sequence of responding for a typical hypnotic subject is shown in the cumulative response curves in Fig. 1. From an initially low operant level, the subject responds appropriately to the rate demands imposed by target levels 3 and 6, being on target most of the time. Instructions to speed up time result in a steeper slope, while instructions to slow tempo lower the response rate. In this case, the slopes of the response curves for the two altered time periods almost converge. The substantial percentage of time the subject is responding at off-target rate levels reveals the extent of asynchronicity between his altered experience of tempo and the constant rate requirements programmed into the apparatus.

Our research design permits both within- and between-subject comparisons. During baseline trials, there were no reliable differences on any measure between groups. An analysis of variance performed on the mean deviation in operant rate from baseline to experimental responding (Table 1) demonstrates a highly significant treatment effect ($P < .001$), and also a feedback effect ($P < .001$) (*8*). Deviation from target level (combined across feedback conditions) significantly differentiated between the hypnotized subjects and those in the other two conditions. The marked deviations from target levels in the no feedback condition were attenuated by providing external feedback. However, as predicted, this feedback served primarily to differentiate between the hypnotized and role-playing subjects. It totally eliminated the asynchrony in responding among the role-players, but the reduced asynchrony of the hypnotized subjects was still substantially different from the other two controls ($P < .005$). Any volitional effect of responding to the tempo instructions as if they were direct suggestions to vary response rate thus appears limited to the no feedback condition. When confronted with information about the consequences of one's behavior, the controls responded with appropriate synchrony, the hypnotized subjects did not. Neither direction of tempo modification (slower or faster) nor target light response level (low or high) was significant.

Perhaps the most convincing data of the extent to which hypnotic subjects altered their sense of personal tempo come from analyses of the pattern of off-target response variability. This measure of variability is the frequency of recorded shifts from one stimulus level to another. The underlying variability in response rate could lead to shifts either around the target level or to shifts around off-target levels. For example, if the target level were 6, shifts to levels 5 or 7 or from them back to 6 would represent around-target shifts. Off-target shifts would be between 7 and higher levels (faster tempo) and between 5 and lower levels (slower tempo). There are no overall differences in total variation between treatments. However, there are significant differences between the hypnotized subjects and controls in the specific pattern of variability ($P < .001$, by Scheffé multiple *t*-test comparisons). The response distribution for the hypnotized subjects was displaced to off-target stimulus levels (in the experimentally appropriate direction), while that of the controls stabilized around the target levels. Thus, in the no feedback condition in which response variability was greatest, subtracting each subject's frequency of off-target shifts from baseline trials to experimental trials resulted in a group mean of +31.0 for the hypnosis condition, but only +1.5 for role-players and −5.0 for nonhypnotized waking controls.

To underscore the critical role of hypnosis in creating a cognitive state receptive to this time distortion manipulation, a subgroup of the role-playing subjects was subsequently given our program of hypnotic training and retested with the hypnotic induction. Four of the five subjects showed sizable changes in the suggested direction. While there were no differences in their standard baseline performance between earlier role-playing trials and these hypnosis trials, there were significant experimental trial differences due to the greater effectiveness of the time-distorting instructions when they were hypnotized (mean deviation in rate: +.51 for level 6, $P < .05$; and +.38 for level 3, $P < .10$).

Interviews and questionnaire responses of the hypnotic subjects indicated that they indeed tried to satisfy the experimenter's demand to keep the target light illuminated, but found they were unable to do so effectively. Their modified sense of personal tempo became a stable reference against which they judged environmental changes. As a result, they believed that the experimenters were covertly altering the apparatus to make their task more difficult (a situational error). By contrast, in an earlier study (*9*) in which clock time had been covertly altered by the researchers, subjects attributed discrepancies between clock and personal time to their own lack of ability in time estimation (a dispositional error).

We believe that a wide range of behaviors and physiological reactions which are under temporal control, such as drug addiction, depression, emotional arousal, and hypertension, may be modified by altering one's sense of personal tempo.

PHILIP G. ZIMBARDO
GARY MARSHALL
GREG WHITE
Psychology Department, Stanford University, Stanford, California 94305
CHRISTINA MASLACH
Psychology Department, University of California, Berkeley 94720

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