Our experience in interviewing a mute patient with this technique suggests that it might prove useful in the treatment of mutism in cases in which the patient refuses to communicate with his therapist in the *vis-à-vis* interview situation.

The fact that several of our patients have commented that machine-mediated interviews were of benefit raises the question of machine therapy for hospitalized patients. In a previous communication, some preliminary efforts in that direction were described (1). We learned from that experience that the programs were too rigid, too weak in handling natural language, and too deficient in utilizing the information that it collected. We are currently working on a program designed to overcome these deficiencies.

The idea behind machine therapy is to provide a communicative experience for a patient which might aid him in dealing with his psychiatric illness. Since computers can communicate with the symbols of natural language, we should try to take advantage of this property in finding ways to help the mentally ill.

CONCLUSIONS

Machine-mediated interviewing has both research and practical applications in psychiatry. As a research tool, it can be used in the study of the techniques of the psychiatric interview, as well as in the development of a more valid diagnostic terminology in which a definition of a diagnostic term is bound to a locus of prescribed interview findings. By limiting the number of communication variables to pure linguistic components, the absence of nonverbal/paralinguistic communication elements is considered an advantage in research design.

Practical applications of this method are in the diagnosis and treatment of individuals at locations remote from treatment facilities (*e.g.*, prisons or rural areas), in residency training, and in the treatment of mutism.

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SOCIAL FEEDBACK: DETERMINATION OF SOCIAL LEARNING

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Social learning was studied by cross-yoking the behavior of two individuals in a manual-visual tracking task so that both persons received an immediate combined or systems error feedback of their socially coordinated movements. A laboratory real-time computer system was used to combine the movement-controlled sensory signals of the two subjects in controlling the combined visual error display. The computer system generated a variable sine wave target for which the two subjects had to compensate by coordinate hand motions. Results on 10 two person groups showed that the interactive systems error was effective in producing progressive and significant learning in the social tracking. Significant learning effects did not occur within trial periods. When compared with results of prior research on learning with series-linked social tracking, the results suggest that systems sensory feedback factors of interactive movements, rather than discrete stimulus response and reinforcing rewards, operate as the primary determinants of social guidance and learning. Real-time systems methods of measuring and controlling social interactive feedback have wide application in creating new objective experimental methods of studying various modes of interpersonal and group behavior.

This experiment defines a new way of studying learning in interpersonal and group behavior by direct measurement of the actual or real-time motorsensory interactions between two or more people, and the use of such measurements to control of systems feedback in two person performance (14, 15, 17). We use the term "social tracking" to refer to such real-time measurement of behavioral interactions between individuals or organisms. Social tracking is defined as the dynamic cross-yoking of the motor and receptor mechanisms of two individuals so that the movements of one constitute a compliant source of feedback-controlled sensory input to the second and vice versa (Figure 1). In this research, we investigated whether learning in crossed social manual-visual tracking is determined by immediate, real-time, systems feedback from interactive performance of two person groups.

The theory of social tracking and learning by systems feedback differs from past operant learning and neo-Freudian doctrines of social behavior and imitation (7, 9, 10, 24). According to social feedback theory, the course and efficiency of performance and learning in social interaction is determined by the different modes and conditions of social tracking. As indicated in Figure 2, three primary modes of social interaction occur in various types of interpersonal and group interaction, *i.e.*, imitative, linked-parallel, and series-linked tracking. The conditions of feedback in each of these modes may vary in terms of positive and negative forms of control, the types of movement information transmitted for crossed sensory control, the ways in which the two individuals are linked to environmental sources of stimulation, and other factors. It is the linked-parallel mode of tracking that was

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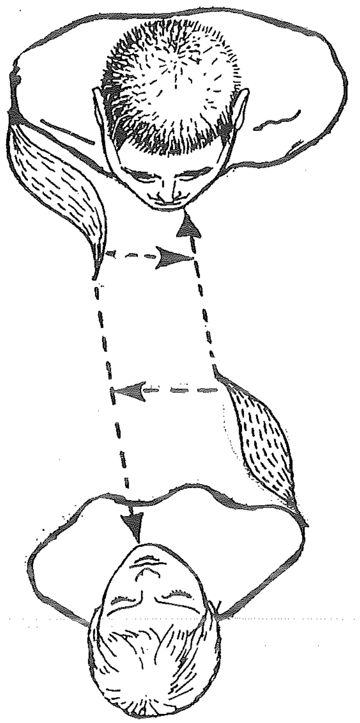

FIG. 1. The concept of feedback control of cross motorsensory interactions in social tracking.

studied in this investigation. This mode of feedback differs from the series-linked situations in that the movements of the two people are integrated on an immediate temporal basis and are not successively time dependent as in the series-linked conditions. In the linked-parallel tracking, the sensory feedback from the two persons may be combined without delay to give a matched systems feedback of their joint performance. The purpose of this investigation was to determine whether such an immediate matched systems sensory feedback can determine interpersonal learning independently of affiliative or stimulus reinforcements that come after the social interaction.

METHOD

Figure 3 illustrates how the experiment was carried out with a computerized social laboratory that was set up to measure joint manual-visual tracking error in real time and to control the display of this error as a systems feedback of performance to two subjects. A laboratory computer system, equipped with a medium-sized scientific computer (Control Data Corporation 160-A) and linked with appropriate con-

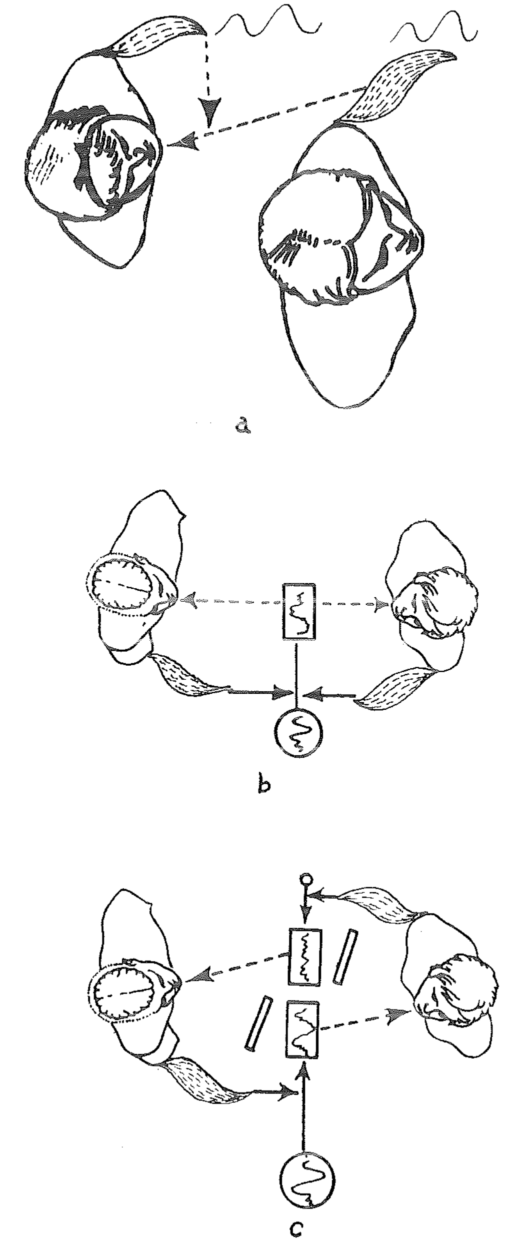

FIG. 2. Theory of the modes of feedback control of social tracking. *a,* Imitative following or steering; *b,* parallel-linked tracking with matched sensory feedback; *c,* series-linked tracking.

verting and signal conditioning equipment, was connected with a social cybernetic laboratory containing both hand control and feedback display apparatus (16). Pairs of individuals, each forming a two person team, were seated before two spring bronze, strain gauge, hand motion transducers, each of which could be moved laterally back and forth for a distance of about 8 cm. The two hand transducers were identical in design and when moved served to activate an oscillograph display located in front of the subjects. The subjects saw the persisting feedback display of their combined error in attempting to negate or compensate a variable sine wave movement of the needle indicator of the oscillograph display. If both subjects moved coordinately to compensate the computer-generated action of the indicator, the persisting error signal appeared as a straight line. However, if either failed to coordinate jointly to compensate the motion of the indicator, an error appeared on the display.

The computerized control of the feedback display by the hand transducers consisted

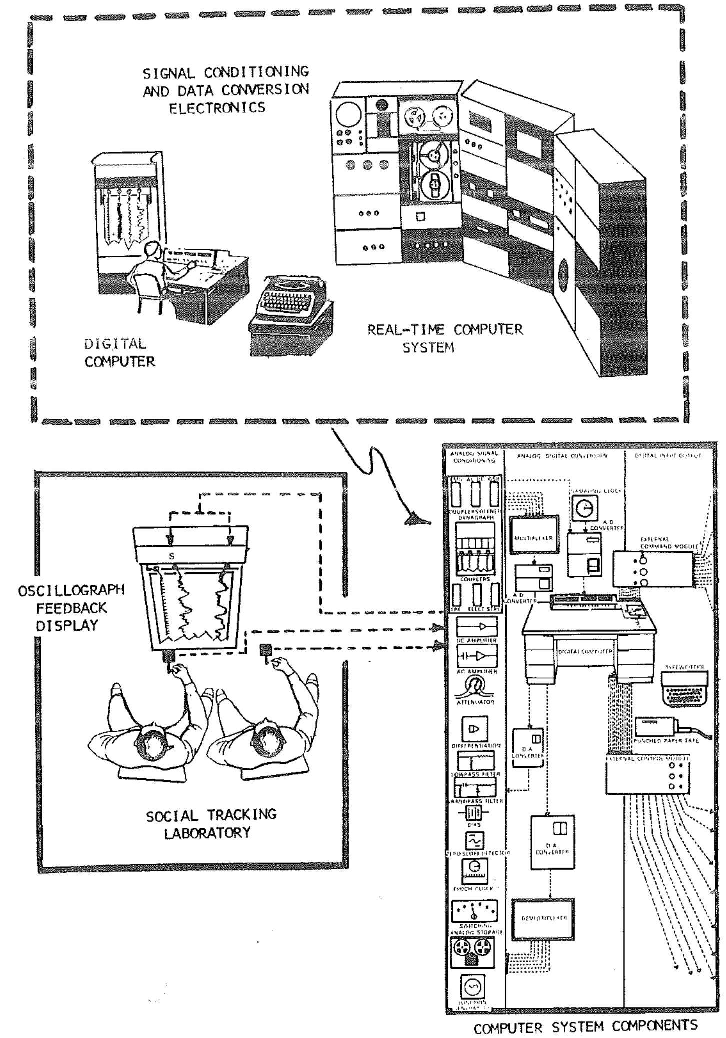

FIG. 3. The social cybernetics laboratory and real-time computer system developed for this research.

of seven major steps. The electrical signals generated by the movement of the transducers were amplified and summed electronically so that each subject had 100 per cent control over the feedback signal. This combined movement signal was then sampled at 128 samples per second and selected by the digital computer. The digital computer then compared this combined input signal with a variable sine wave signal that was generated by the control program of the computer and computed the difference between the two signals to obtain the systems error. This systems error was then transmitted to the digital-analogue converter, converted to analogue form, and amplified. This analogue signal was then displayed on the oscillograph, which the two subjects tried to control.

In addition to controlling the systems feedback for the subjects' oscillograph display, the computer system also amplified the separate movement signals of the hand motion transducers and recorded these on hidden channels of the oscillograph (Figure 4). In addition, the target signal was also recorded as a separate trace on the oscillograph. The computer was also programmed to automate all aspects of the experimental observations on given pairs of subjects, *i.e.*, storing the measures of systems error, scheduling trials and rest periods between trials, and giving instructions to subjects.

The subjects of the experiment were 10 pairs of male and female subjects arranged in two person teams in an unbiased way. Each pair of subjects received 20 trials each, 1 minute long, separated by rest periods of 30 seconds. During each trial, the computer summed the systems tracking error over 5-second intervals giving 12 separate period error means for each trial. Before observations began, each pair of subjects were instructed regarding the detail of the experiment and were given one trial as a demonstration.

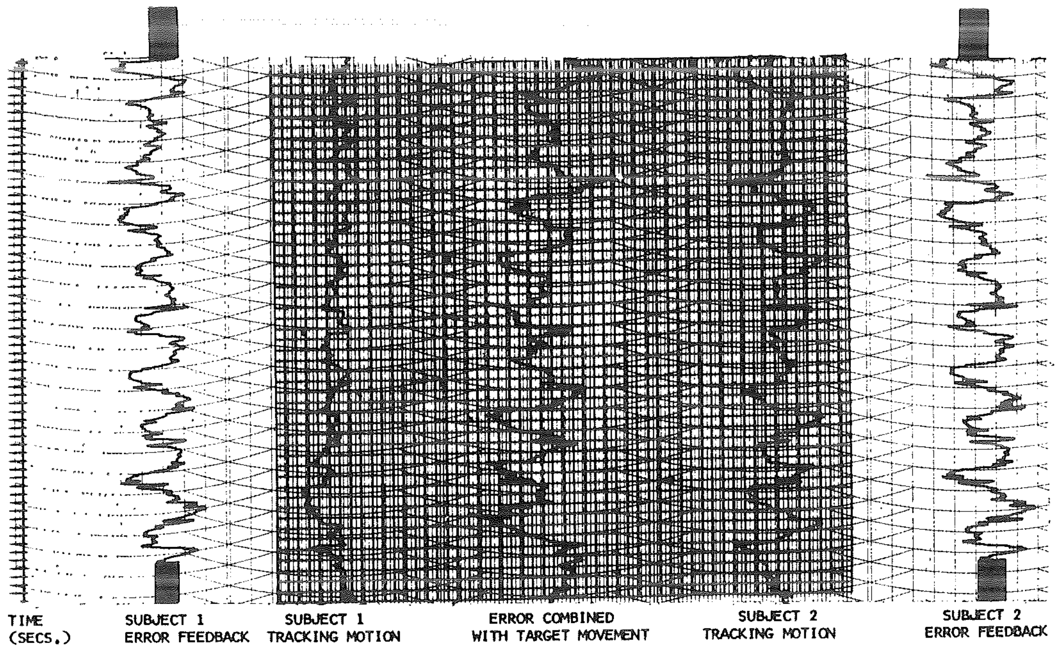

FIG. 4. The six traces of the oscilloscope display. The feedback displays of error for the two subjects in each two person group were identical.

RESULTS

The results consist of a learning function for the 20 trials of practice, within-trial learning changes, and oscillograph records describing the movement characteristics of performance. The main learning data are given in Figure 5 in the form of a learning curve that plots relative tracking error (as expressed in digital voltage values) as a function of trials of practice. The curve shows that progressive learning occurred throughout the initial 15 trials of practice with the main learning effect occurring in the first 8 trials. This progressive social learning is of special interest because individual hand motion tracking, like that used here in a social situation, ordinarily shows only the most limited learning changes and often none at all.

A three way analysis of data was performed on the learning data (Table 1). The results showed that besides the differences between group means, the differences between trial means also were statistically significant ($F = 13.27, p = .01$). The variations in performance in the 12 measurement periods within trials were not statistically significant.

The variation in performance for subject teams was marked. The best team gave an error level of 10.0 while in the worst team the error level was 30.2, or 300 per cent that of the best team. Two groups gave high error scores around 30. Seven subject groups produced error values between 12 and 20. Thus, the large majority of the subject teams were more or less uniform in their coordinate activity. Figure 6 illustrates the course of learning in every other trial of the 20 trials for one subject team. This team was the best of the 10 teams. Each set of records displays six traces, which are, from left to right: 1) time in seconds; 2) systems error feedback to the first subject; 3) movements of subject 1; 4) error combined with the target wave; 5) movements of subject 2; 6) systems error feedback to the second subject. Comparison of the movement traces of the two subjects over the 10 trials shows that the strategy of the two individuals in reacting to the joint task was quite different. Subject 1 produced a great many rapid movements that progressively decreased in amplitude with practice. In contrast, the movements of subject 2 tended to be adjusted more to the target variation produced by the computer. In contrast to these movement records, the movement traces for the poorer subject teams varied widely over the limiting ranges of the record. In some of these teams, however, the learning effect over trials in the error traces were more

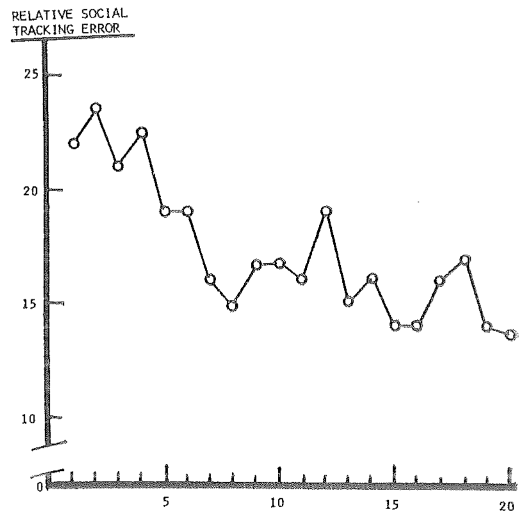

FIG. 5. Learning function for matched, parallel-linked social tracking.

TABLE 1

Results of Analysis of Variance for Practice Trials

Source	*DF*	Mean Square	*F*
Subjects	9	11517.40424	117.18*
Trials	19	876.64124	13.27*
Periods	10	9.33700	
Subject × trial	171	424.74364	6.52*
Subject × period	90	46.60902	
Trials × period	190	189.22772	2.86*
Subjects × trials × periods	1710	65.95450	
Total	2199	157.32952	

* Significant at 1 per cent level of probability.

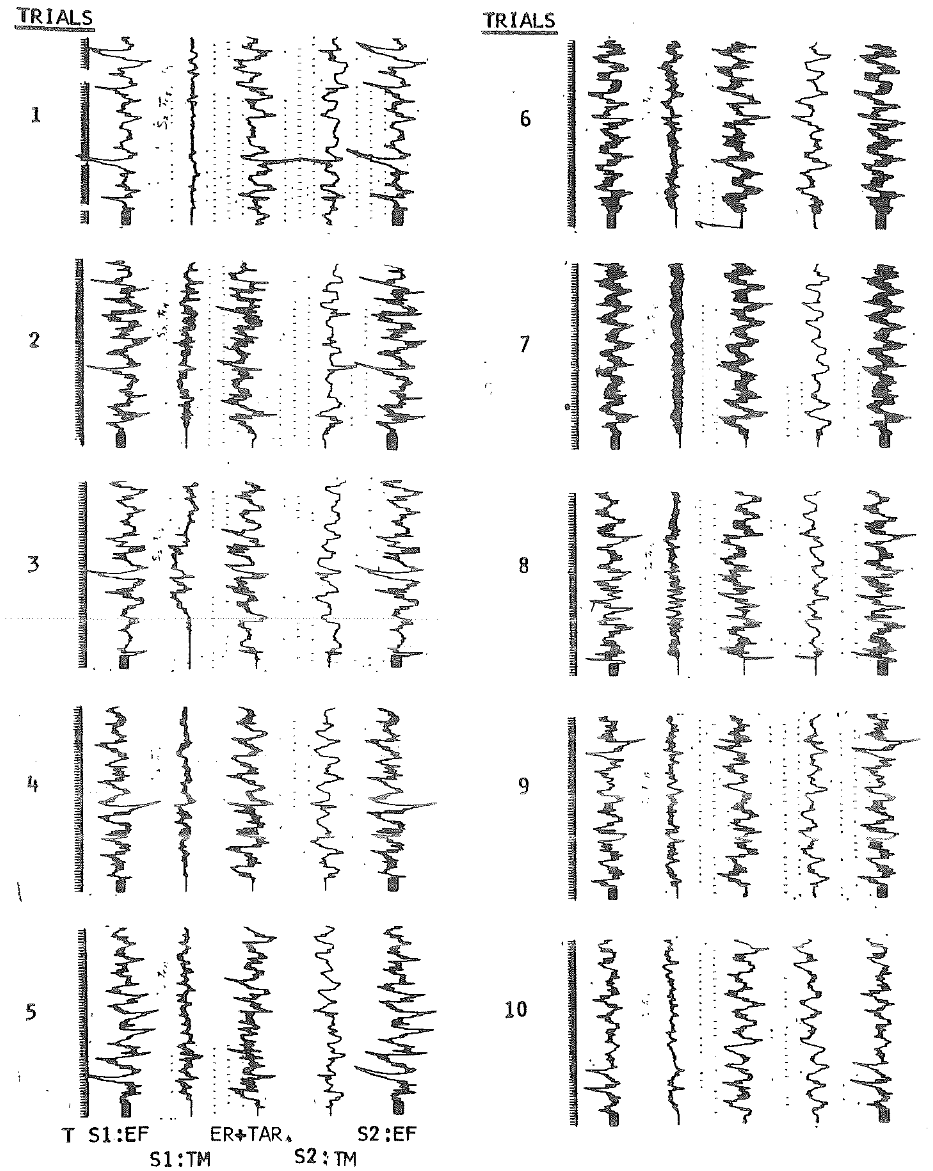

FIG. 6. Oscillograph records showing changes in individual movements and team error during learning.

marked than that of team 1. Generally, the best teams tended to show somewhat the same differentiation of movements as that observed in the two subjects of team 1.

DISCUSSION

This experiment has tested the validity of the theory that learning and performance in social interaction is based on the systems interaction between two or more persons in social tracking and not upon affiliative stimulus rewards and reinforcements which come after coordinate, interpersonal movements. In the theory, social tracking is defined as movements based on mutual cross-yoking of the motor and sensory systems of two or more persons so that the movements of one constitute a source of

reaction-controlled sensory feedback for the second and vice versa. According to this interpretation, the modes, parameters, and conditions of this feedback linking of the cross-motorsensory mechanism can vary in many different positive, negative, and compensatory parallel and series ways. A main assumption of the theory is that a combined systems indication or comparative feedback indication of the error of combined movements is necessary to produce optical learning in social interaction.

The results obtained here confirm the present systems feedback assumption of social feedback theory. They showed that significant learning occurs consistently in subject groups with only a systems error feedback to guide their interrelated yoked movements. To learn, the two subjects of each two person team had to adjust their movements, not simply to the target variation generated by the experimental apparatus but to motions of each other as indicated by a comparative or combined systems error. They had no specific discrete stimuli from each other to control their movements.

The present experiment is not the first to study joint tracking by small groups, but it is original in specifying and testing the role of particular kinds of systems or interactive measures of interindividual behavior in determining social performance and learning. Initial studies in this area (2, 8, 12, 13, 23) attempted to analyze social learning in terms of arrangement of the structure and types of communication in small groups. Another series of studies (3, 6, 11, 24) investigated team coordination in discrete activities and determined that proficient team members tended to compensate the action of poorer members but that such social compensation could occur only when the better individuals were put in positions to make compensation effective (5). A third research area (4) investigated joint tracking of gunnery teams and found them extremely hard to train. This difficulty could be overcome to a limited extent by putting experienced persons in with trainees. Still another area of investigation created simulated team feedback by combining the error of independently performing subjects and presenting these simulated team errors (7).

Past studies (6, 7) of social behavior and learning nearest to the present investigation dealt with this artificial effort to produce a simulated team feedback of performance. This study involved measurement of the independent tracking performance of two subjects, who were told 15 seconds after their performance what their average error may have been. Besides involving a number of errors in combining scores on a summed or nonreal time basis, this experiment also confused the meaning of immediate sensory feedback that persons need to guide their movements in relation to one another and informational knowledge of performance that can occur long after performance was over. The fact that the results of these experiments were interpreted as the expression of reinforcement in social learning is of particular significance inasmuch as the findings were that no significant learning actually occurred with the simulated team feedback.

By crystallizing the difference between real-time, movement-integrated sensory feedback essential for mutual guidance of interpersonal actions and open loop informational reinforcements or delayed knowledge of results, which come long after social responses occur, this study defines improved methods and theory in controlled experimentation on social intercourse of all types. As suggested earlier, it is possible to relate the social cybernetic specifications of modes of interpersonal feedback to many variable conditions of positive and negative linking of persons in such activities as parent-child interaction (21), teaching and education (18), training designs in rehabilitation and behavior therapy (20), and team performance in athletic skill and learning (19). The main conclusion from this past research is much like that reached here, that immediate combined systems feedback indicating the guidance and synchronism of interpersonal movements is essential for social learning.

This study adds to prior research on social, manual-visual tracking and learning in showing that the persisting systems indication of error or accuracy in linked-parallel tracking, may be superior to series-linked modes of social tracking (14, 15). The parallel systems mode of crossed motorsensory feedback studied here produced more learning than that observed earlier in television- and computer-controlled series-linked modes of interpersonal, manual-visual tracking and tracing. We believe that this difference was due to the fact that intrinsic feedback delay factors were involved in the earlier individual series-linked performances. These differences in learning under different modes of social tracking provide direct evidence for the view that interpersonal and group interaction are specialized and determined primarily by social feedback factors. The oscillograph records of movements and systems errors obtained during learning in this study suggested that the systems indication of error operated mainly to give an immediate sensory feedback of coordinate synchronization of movement which could be used selectively to control accuracy and thus to organize motions for learning.

This experiment adds to earlier results on social tracking in infants (15, 21), which indicated that the development of social tracking is influenced by movement-controlled responsive displays of active parents and other people. The initial findings on the effects of dynamic movement on social tracking in babies give evidence for the view that active interplay between children and others contributes to development and learning by producing comparative synchronized sensory effects of interactive responses which can serve as a basis of guidance of performance and learning. These results, like the present findings, support an earlier view (22) that social performance is determined by built-in factors of imitation or guided following which can serve as the basis for social development and learning. They contradict, however, current social psychological views that neo-Freudian learning factors and operant reinforcements, which occur subsequent to social responses, can have a determinative role in "shaping" the movements involved in imitation (1, 9, 10). We believe that guidance of social response and learning is just as much if not more dependent on immediate sensory feedback of dynamic movement as the most refined modes of individual behavior.

The type of data and the general methods of social tracking described here have many applications in clarifying interpersonal and team functions in work, athletics, and intimate social behavior. Past theory and methods have not brought out the refinements of real-time motorsensory control and skill needed in social interactions. It is the existential closed loop events of such interactions and not the promise of later rewards which determines the extent to which two or more people can learn to behave as an efficient organized system. When two people can cross-yoke their motor and sensory systems in a linked way, they can coordinate their movements and physiological operations as a single system and thus can learn progressively in terms of the sensory effects of their synchronized actions. When such synchronized feedback effects of movements are lacking, they cannot learn socially in an effective way.

The methods of this research illustrate one of many examples (16) of applying experimental systems methods to research in social psychology. Such methods involve more than use of computers to simulate or process data regarding social behavior. Rather, they entail the design and application of laboratory setups and dynamic programming techniques to control and measure systems feedback parameters of interpersonal and group behavior. Therefore, they make possible development of an experimental social science that deals with the actual real-time motorsensory interactions that go on between two or more people in interpersonal and group response. We believe that such methods represent a new horizon for study of both refined social skills and communication and of the limitations in social behavior characteristics of emotionally disturbed and socially deficient persons. Our view is that the many forms of emotionally limited behavior involve major deficiencies in social tracking and related processes of physiological interaction.

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