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AN INFORMATION PROCESSING INTERPRETATION OF IDEOMOTOR BEHAVIOR IN THE CHEVREUL PENDULUM ILLUSION

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AN INFORMATION PROCESSING INTERPRETATION OF IDEOMOTOR BEHAVIOR IN THE CHEVREUL PENDULUM ILLUSION

by

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ABSTRACT

AN INFORMATION PROCESSING INTERPRETATION OF IDEOMOTOR BEHAVIOR IN THE CHEVREUL PENDULUM ILLUSION

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RANDOLPH D. EASTON

A series of investigations was undertaken to quantify ideomotor behavior in the Chevreul pendulum illusion and pursue its ramifications within an information processing framework. Historically the pendulum effect had been treated merely as a standard test of "suggestibility." Concerns for the perceptual/cognitive implications of ideomotor behavior tended to be ignored or absorbed into now antiquated theories. Recent developments in cognitive psychology regarding processes of nonverbal representation indicated that an updated interpretation of the ideomotor principle would have theoretical utility.

Two studies were initially designed to quantify the pendulum effect. Findings were that the magnitude of covert muscle expressiveness accompanying imaginal activity was systematically related to the deployment of cognitive resources, the amount of musculature used to suspend the pendulum, the presence of visual reafferent feedback (i.e., sight of the actual build-up of pendulum oscillations), and the presence of visual and auditory external stimuli which

served as imaginal prompts. Visual imaginal prompts were found to exert a stronger facilitative influence on the ideomotor process than auditory prompts.

A third experiment was designed to explore the difference between visual and auditory signals on imaginal activity and make the overall experimental method more precise. Findings from the systematic comparison of electrically automated imaginal prompts indicated that visual signals exerted a stronger effect in spite of deliberate attempts to embellish the auditory prompts. The working interpretation of this finding was that visual and auditory information are processed in different channels. Visual signals are more directly incorporable into visual imagination, while auditory signals require an extra transformation to a visual form before being readily actualized in behavior.

Two additional experiments were designed to test this interpretation. The parameters of the oscillating imaginal prompts were systematically manipulated relative to the periodic, sinusoidal motion of the pendulum, creating conflicting processing between perceiving and imagining. Findings from these experiments revealed an interaction between the conflicting stimulus situation and the modality of information constituting the stimuli. Visual imaginal prompts when compatible with what was presumed to be visual imaginal activity strongly facilitated the ideomotor process, but as they became less compatible their effects became disruptive. In contrast, the facilitative and disruptive effects of auditory prompts when present, were substantially less pronounced. The nature of the interaction again suggested that visual images and signals may be processed in the same visual channel while auditory images and signals are processed in a separate channel.

A final set of experiments explored the effects of analog reafferent feedback on the ideomotor process. While certain differences in the effects of analog feedback and external signals on the ideomotor process emerged, the findings from the feedback studies provided further support for the two channel hypothesis for processing visual and auditory information. As the analog feedback was delayed relative to the actual pendulum motion the magnitude of pendulum oscillations decreased. This disruptive effect, however, occurred only for visual feedback. Delayed auditory analog feedback did not disrupt visual imaginal processing.

The findings and interpretations of these studies represent a substantial elaboration on the old nineteenth century ideomotor principle. The present evidence also converges on findings in the literature dealing with the effects of conflicting perceptual and imaginal processing. In addition to being viewed as a standard test of "suggestibility" the pendulum effect represents a useful experimental method to explore imaginal processing. The validity of the method would be further enhanced if other measurable examples of ideomotor behavior proved sensitive to manipulations which put imaginal and perceptual processing in direct conflict.

I. INTRODUCTION

It is a common experience that many of our actions appear to follow immediately and unpurposively the mere thought of that action in consciousness. When observing someone yawn there often occurs what seems to be an irresistable tendency for one to yawn himself. While at an athletic contest a spectator may find himself mimicing the participants with slight or even fairly large muscle movements. The everyday conversation of some individuals is accompanied by what appear to be nondeliberate arm and hand expressive gestures which correspond to the rhythm and articulation of their speech. These and numerous other examples can be taken as representative of the tendency of ideas of actions to become actualized in behavior even without the volitional intent to do so.

William James in 1890 aptly conceptualized these phenomena into an issue for psychological scrutiny by posing the following question: "Is the bare idea of a movement's sensible effects its sufficient mental cue, or must there be an additional mental antecedent, in the shape of a fiat, decision, consent, volitional mandate, or other synonymous phenomenon of consciousness, before the movement can follow [James, 1890, II, p. 522]"? By answering "yes"--that the bare idea is sometimes sufficient--James placed this phenomenon among the intriguing peculiarities of mental functioning, noting that William B. Carpenter first referred to it as ideomotor action. In fact, James placed ideomotor action at the center of his theory of volition: an image of the sensory consequences of a voluntary act was sufficient to awaken in some degree the actual movements constituting the act.

Some of the most striking elaborations on the principle of ideomotor action can be seen in the spiritualistic movement which swept Europe during the middle of the 19th century. At that time mesmerism (hypnotism) as conceived and practiced by the intellectual descendants of Mesmer and Puységur was supplemented by other techniques aimed at unfolding the "powers" of the mind. By the middle of the 1850's study groups in many countries were busily engaged in various mystical activities including trying to communicate with spirits of the dead (Ellenberger, 1970). By utilizing various special techniques the practitioners allegedly permitted deceased spirits to manifest themselves in various ways, thus allowing living persons to establish forms of communication with the spiritual world. Some students of these occult arts, the so-called "mediums," were able to write automatically, speak in a trance and supposedly call forth the occult occurrence of various physical phenomena.

One of a number of physical objects mysteriously incited to movement was a pendulum-type device consisting of a weighted body suspended by a cord from the fingers. The pendulum was found to oscillate back and forth when willfully concentrated upon, seemingly of its own accord. The movement was hastily attributed to mystical forces. Intrigued by the small pendulum, the distinguished French chemist, Michel Eugéne Chevreul, applied his talents to its study. Chevreul's systematic explorations helped to bring the study of what we now regard as "suggestibility" and the many once popular devices for exploring it--the automatic writing planchette, the turning table, the talking table, the divining rod, the ouija board, and the Chevreul pendulum --into the boundaries of science. All of these phenomena came to be interpreted as examples of involuntary muscular movements occurring under conditions of expectant attention.

Chevreul found several allusions to the miraculous pendulum in books on the curiosities of physics in the seventeenth century and even a reference to its use as a means of telling time in the fifteenth and sixteenth centuries (Jastrow, 1935). He was also familiar with the work of a small group of experimenters, led by Professor Gerboin of Strasburg at the beginning of the 19th century, who were attempting to give the mysterious movements of the pendulum scientific meaning.

Chevreul (1833, 1854) observed that an iron ring suspended by hemp from the fingers would oscillate over certain substances without conscious deliberation or volitional intent. Other substances such as a sheet of glass or a block of resin were found to stop the oscillations when interposed between the pendulum and an underlying tank of mercury. Once the intermediate body was removed the oscillations reappeared. Impressed by the remarkable constancy of the phenomenon, Chevreul next set out to determine if the effects were indeed unrelated to muscular movements as he had been assured by others. An apparatus was built which allowed the arm holding the pendulum to be supported. As the support was moved from the shoulder toward the hand, oscillations were found to decrease. When the fingers holding the cord were stabilized, movement virtually ceased. He concluded that muscular movements taking place without the operator's awareness were in some manner responsible for the oscillations. Further, it was his impression that the open eyes following the iron ring resulted in a disposition toward movement which became increasingly fulfilled as the sweeps of the pendulum broadened. As a result, the experiment was repeated with the arm unsupported but with the operator blindfolded. The blindfold was applied once the pendulum was in motion above the mercury. Without sight of the movement, the oscillations were found to decrease markedly. As in the first experiment, glass and resin were again interposed between the pendulum and mercury, though in this instance without the operator's knowledge. The now feeble oscillations were not further diminished, as they previously had been.

On the basis of these results Chevreul came to view the oscillations of the pendulum as a kinesthetic illusion. It was an illusion because the operator did not feel his muscles initiate and maintain the movements, when, in fact, they were the sole agency. A necessary precursor to this illusion was found by Chevreul to be the presence of visual sensations; the resultant tendency toward movement somehow depended on the feedback of visual information. In addition, Chevreul concluded that a particular state, analagous to what the mesmerists called "faith," was also required. As long as one expected or believed in the possibility of movement it would be more likely to ensue. It was this latter observation which was given theoretical primacy under the concepts of suggestion and suggestibility; the interpretation of the Chevreul pendulum effect has been handed down into our modern era under these latter terms--i.e., as a standard test of suggestibility. The other observations leading to conceiving of the effect as a kinesthetic illusion, worthy of study in its own right, tended to be ignored or absorbed into theoretical formulations which have since become antiquated.

By the end of the 19th century Chevreul's claims had been substantiated by a number of other investigators (Mayo, 1851; Carpenter, 1884; also see Easton, 1972). According to Carpenter the ostensibly autonomous movements of many physical objects thought to represent communications with the dead could be reduced to a single principle. As stated by Carpenter: ". . . in certain individuals, and in a certain state of mental concentration, the expectation of a result is sufficient to determine,--without any voluntary effort, and even in opposition to the Will--the Muscular movements by which it is produced [Carpenter, 1884, p. 287]."

Although ideomotor behavior has not been studied directly since then, research conducted during the present century on waking suggestion (Estabrook, 1929; Hull, 1933; Arnold, 1946; Eysenck, 1947; Eysenck & Furneaux, 1945; Benton & Bandura, 1953; Evans, 1967) and the early behavioristic-peripheralist doctrines (Watson, 1930; Jacobson, 1932; Max, 1935, 1937) demonstrated a concern for the intimate relation between internal symbolic activity and the non-deliberate muscular expression of that activity.

Lacking in all of these endeavors, however, was an emphasis on the cognitive processes underlying ideomotor behavior. The early behaviorists transformed the ideomotor construct into a broad empirical framework which purported to permit the objective study of subvocal speech, which to them meant the study of all human thought. Investigators of waking suggestion placed emphasis on the relationships among suggestion, hypnosis, and personality, leaving the parameters of ideomotor behavior unstudied.

Two contemporary lines of research, however, suggest the utility of the ideomotor phenomenon as a means of exploring certain cognitive processes. Due to a renewed interest in a mental imagery, reliable empirical methods are being devised to study nonverbal representational processes (Sheehan, 1972). At the same time electromyographic techniques have provided substantial evidence demonstrating that implicit muscular activity accompanies and correlates with thinking and mental imagery (McGuigan, 1966, 1970). Whether or not a motor theory of consciousness has validity (Smith, Brown, Teman & Goodman, 1947; Smith, 1964, 1969), it is evident that experiments designed to explore the topography of covert muscle movements which accompany the symbolic processes should help elucidate the nature of imaginal representation. This report describes the development of a method aimed at exploring the relations among ideomotor behavior, imagery, the perception of external stimulation and reafferent feedback.

II. THE OBJECTIVE QUANTIFICATION OF THE PENDULUM ILLUSION

The first task of these studies was an analysis of the physics of a pendulum's motion and the development of a dependent index representing the amount of the Chevreul pendulum effect. A pendulum held in the hand is essentially an amplification device, since the damping factor or frictional force of the fore-finger and thumb acting on the pendulum is relatively small. Very small muscle movements accompanying corresponding imagery can be magnified into large pendulum sweeps provided that such periodic forces transmitted by the body musculature occur at or near the resonant frequency of the pendulum. To take a familiar, simple example the pendulum works the way a child's swing works.

It rapidly became obvious in pilot work that most subjects would produce quite wide pendulum swings under favorable conditions and that the oscillations could be rendered negligible under other conditions. Subjects also reported that the experience of seeing the pendulum move seemingly of its own accord was surprising and inexplicable at first. They could soon be led to realize that their own minute muscle movements must be the causal agent, but their experience of non-volitional movement remained illusory and subjectively compelling. These reports matched the phenomenal observations of the experimenters and the other investigators who visited the laboratory. The illusion can be quickly verified as a compelling subjective effect by the skeptic. It was understood that any subjects who produced pendulum movements but did not find the pendulum movement illusory would have to be excluded from the investigation; none were found, however. Some subjects produced very little movement but whatever movement they produced was illusory. Many subjects reported that after the fact they were aware that their muscles were making slight movements, thus causing the pendulum to swing, but that the muscle movements themselves were nondeliberate--which is, of course, the crucial point. While the problem of the ultimate trust to be placed in subjective impression will not be solved in these studies, it seemed a cogent heuristic to take the extent of pendulum movement as an operational index of the amount of non-volitional muscular expression of imagined activity--or, in brief, as an index of the amount of kinesthetic illusion. After considering other possibilities, the angle subtended by the arc of the pendulum swing was chosen as the most stable and convenient physical measure of amount of movement (Easton, 1972).

The first question asked in a series of experiments designed to quantify the pendulum effect was whether the pendulum moves simply because the hand cannot be held absolutely still. A conceptual analysis of the physical principles of the pendulum reveals that all excitatory movements not in or near the resonant frequency of the pendulum will lessen the resonant energy of the system (Crandall & Marks, 1963). As only a small portion of natural bodily movements would be in phase with the period of the pendulum, the overall effect of random movements would be to attenuate the resonant energy. The periodicity of covert responses accompanying Ss' imagined pendular movement, however, should be close to the resonant frequency of the pendulum allowing it to act as a mechanical amplifier. A very simple initial experiment was designed to substantiate this argument empirically. The magnitude of ideomotor action or swing of the pendulum was compared when Ss imagined the pendulum move back and forth, imagined the pendulum remain absolutely still, or maintained as neutral an attitude as possible with regard to pendulum motion.

Experiment I

Method

Apparatus and materials. The pendulum bob consisted of a silver colored 35-mm film canister, 45 mm high by 30 mm in diameter with a tapered top, weighted to three ounces. Attached to the center of its top was a 3 mm in diameter white nylon cord 61 centimeters long. When in use the pendulum was held in front of a 90 cm high by 60 cm wide black backboard mounted on a 30 cm high pedestal; the S stood behind the backdrop, extended the hand holding the pendulum over its top, and looked down at the pendulum against the black top of the pedestal. A 16-mm movie camera with facility for single-frame time exposures was positioned to take photographs of the backboard area. The white pendulum held in front of the black backboard permitted time exposure photographs of the pendulum's side-to-side motion with excellent contrast and clarity.

Timers were arranged to provide a 30 second delay interval after the onset of a trial followed by a six second single frame time exposure. The 30 second delay interval allowed time for the pendulum to overcome inertia and build up to a stable level of motion. The six second time exposure allowed the pendulum to sweep out about four cycles of oscillation. As hand movements were uniformly very small during the trial the picture on the negative consisted of a shaded isoceles triangle with a curved base, representing the area of the pendulum's motion. Protractor measurements of the angle of the apex of the triangle were taken directly from an enlarged image of the negative frame. Inter- and intra-judge differences were found to be random and within 0.2 degrees yielding reliability coefficients of .95 and above.

Subjects. Five male and five female introductory psychology students fulfilling course requirements at the University of New Hampshire served as *S*s.

Procedure. *S*s were run individually. Upon entering the experimental room *S*s were told that the experimenter was interested in studying imagination and concentration. They were informed that their basic task was simply to hold the pendulum between thumb and forefinger over the backboard, and while keeping their eyes on the pendulum to perform certain cognitive tasks as instructed. Subjects were asked to refrain from moving the pendulum deliberately. They were told to keep their head and body relaxed but still. They were asked, as far as their basic task was concerned, to try to exclude other thoughts from active processing. The E attempted to maintain a neutral, detached attitude while conducting the experimental session.

About five minutes were then spent in administering a standard set of practice trials to provide warm-up and allow the Ss to become familiar with the general task.

The Ss were asked to perform three different cognitive tasks. On some trials they were asked to imagine the pendulum moving back and forth, wider and wider. On others they were asked to imagine the pendulum remaining absolutely still. Finally, on some trials they were asked not to think about the pendulum at all; to remain as neutral as possible regarding pendulum motion.

The experiment consisted of four blocks of three trials each. Each trial consisted of the performance of one of the tasks with the order randomly determined within a block for each S. The experimenter initiated a trial by signaling S to begin concentrating. This was followed by the 30 second build-up interval and the 6 second time exposure measurement interval. Subjects were provided the opportunity to relax 15 to 20 seconds between trials. The four measures of pendulum movement for each task were averaged prior to analysis.

Results

The data were analyzed by means of a one factor ANOVA with repeated measures. The means for the three instruction conditions are presented in Table 1. The instructions factor resulted in a significant main effect (F (2,18) = 14.72, $p < .001$). (Complete ANOVA summaries for all experiments described in this report appear in the Appendix.) The Newman-Keuls comparison indicated that the movement of the pendulum was significantly greater when Ss imagined movement than when they imagined no movement or remained neutral (p's $< .01$). The latter two conditions did not differ significantly.

The simple but important implication of this result is that the pendulum can be held still and thus its movement must be the result of some mediating cognitive process. By further isolating the parameters which reliably influence the pendulum effect, it was reasoned that the nature of those cognitive processes could be unraveled. Therefore, as a next step toward this objective, a second more comprehensive experiment was designed.

Experiment II

Four questions were posed in this study.

1. What will be the influence on ideomotor movement of requiring subjects to perform other cognitive tasks simultaneously with concentrating on imagined pendulum movement? In other words, to what extent will the division of attention and deployment of cognitive resources elsewhere required by

these simultaneous tasks either inhibit the ideomotor movement or perhaps facilitate its freer, less inhibited expression? Two specific concomitant tasks were compared with an uncomplicated condition.

The first of these was requiring Ss to concentrate on the idea of holding the hand still while simultaneously concentrating on the idea of pendulum movement. While this task of imagined stillness does not seem in itself cognitively demanding, it does appear inherently contradictory to the idea of pendulum movement.

The second task was counting aloud backwards by threes while simultaneously concentrating on the idea of movement. The counting backwards task is known to be cognitively demanding but does not appear to be inherently contradictory to the idea of pendulum movement.

This second concomitant task thus appears to be at opposite poles from the first in regard to both cognitive demand and inherent contradiction of dual task components. It was predicted that the task of imagined stillness (similar to some Ss' own inhibitory thoughts regarding pendulum movement) would interfere with the ideomotor effect but that the counting backwards task would facilitate it. The latter prediction stems from historic conceptions of "indirect suggestion" which would hold that the added task of counting backwards would permit the expressive tendency of the image of movement freer reign since there would be less capacity within attention for thoughts which could impede motoric expression (Shor, 1972).

2. What will be the influence on ideomotor movement of providing visual and auditory imaginal prompts to Ss rhythmically coordinated with the period of the pendulum? The crossed combination of two factors, each with two levels, was used to investigate the question. The first factor involved the presence or absence of visual prompts in which the experimenter moved his hand rhythmically back and forth beneath the pendulum. The second factor involved the presence or absence of auditory prompts in which the experimenter spoke the words "back" and "forth" in cadence with the period of swing.

It was predicted that both types of prompts would augment the ideomotor effect, that their influence would be additive, but that the visual prompts would have the larger and more reliable facilitative influence. These predictions were made on the hypothesis that the visual prompts would be incorporated into the process of imagining movement in a direct perceptual way, whereas the auditory prompts would first have to be transformed into visual imagery before they could be incorporated. The imagination of movement, the ideomotor movement, and the visual prompts all have the same spatial character and occur in the same visually perceived space. The auditory prompts are in a different sensory modality, lack a spatial component, and so are more abstract, more symbolic, and thus would seem less directly incorporable.

3. What will be the effect on ideomotor movement of varying the amount of unrestrained musculature than can

contribute to pendulum movement? Two conditions were compared: free standing, so that the entire body musculature could be involved in the pendulum movement, and wrist restrained, in which the wrist was held in a restraining cuff so that only the muscles of the hand and fingers could contribute to the pendulum movement. The prediction was that the pendulum motion would be largest when the entire musculature was free to participate in the representation of movement.

4. Is there a sex difference in ideomotor behavior? It was observed in pilot work that females produced considerably wider pendulum swings than did males, and so it was predicted that they would do so also in the formal investigation. Sex was included as a person variable in the study for its own sake and also to help lessen unaccountable between-subjects variability.

To see why the qualification of the pendulum effect is important and why these particular four questions seemed to us the most basic and theoretically interesting set to include in this second study, it is instructive to contrast the writer's theoretical viewpoint with the traditional conception of ideomotor behavior. Ideomotor responsiveness has traditionally been conceived as one manifestation of suggestibility. Suggestion implies that the subject's thoughts and actions are somehow under the control of influences other than his own voluntary choice. It refers to some kind of obligation or heightened inclination to respond to a special category of ideas or influence communications labelled generically as "suggestions." While the giving up of control over one's own reactions is only partial, temporary, and usually with the subject's cooperation, nonetheless susceptibility to suggestions is seen as some kind of susceptibility to controlling influences which operate beyond the bounds of voluntary compliance (Shor, 1970).

It is believed that the more fundamental point is missed when the Chevreul pendulum effect is viewed merely as the manifestation of susceptibility to "suggestions." From the alternative viewpoint espoused here,the effect is conceived as fundamentally a kinesthetic illusion which occurs under favorable conditions because of the way the sensory/motor and representational mechanisms of the human organism are structured. The illusion simply has to occur as a natural, motoric by-product of imagining pendulum movement if only the subject does not inhibit it. The ability to produce a strong amount of illusion depends on a cognitive ability, a skill for effectively implementing one's imagination voluntarily in an organismically coordinated way. While it shall doubtless be found in future studies that factors of social pressure, conformity, demand characteristics, etc., will influence the amount of Chevreul pendulum illusion, it is believed that the manifestation of cognitive abilities and not merely a type of lack of control is being studied.

Method

Apparatus and materials. The apparatus and materials were identical to those used in Experiment I except for the addition of a removable restraining wrist cuff which was affixed to the top of the backboard.

Subjects. Thirty male and thirty female introductory psychology students fulfilling course requirements at the University of New Hampshire served as Ss.

Procedure. The introduction of Ss to the experimental session and preliminary instructions were the same as those in Experiment I. About five minutes were again spent in administering a standard set of practice trials to provide warm-up and allow the Ss to become familiar with the general task. Although a given S would later be assigned to only one of the three independent instructions conditions, practice trials were given under all three and were crossed with a standard set of selected levels of the repeated measures factors. As a precautionary measure E remained unaware of which instructions group the S would later be assigned to until after the practice trials were over.

The design is summarized in Table 2. The factoral combination of the two between-Ss factors of instructions and sex produced six independent groups. Ten male or female Ss were randomly assigned to each of these six groups.

Subjects receiving the first type of instructions were told to concentrate on the hand remaining still in addition to concentrating on the image of the pendulum moving.

It was pointed out that this instruction did not mean to deliberately hold the hand still but only to imagine it remaining still. The second type of instructions was the uncomplicated condition of no concomitant task. Subjects were told to concentrate solely on the image of the pendulum moving. Subjects receiving the third type of instruction were required to count backwards aloud by threes from a randomly selected two or three digit integer while simultaneously concentrating on the image of the pendulum moving. They were asked to count backwards at a steady continuous pace but were told not to be overly concerned about mistakes nor to make corrections. All Ss were told that on some trials the E would present visual and/or auditory stimuli that were to be used if possible to strengthen imaginal constructions and involvement.

Each S received the crossed combination of three within Ss factors consisting of two levels each: musculature involved in suspension, visual prompts, and auditory prompts. Three measures were taken for each of these eight treatment combinations in three blocks of eight randomized trials. In all, each S received 24 experimental trials; the three measures of each type were averaged prior to analysis.

Results

The data were analysed by means of a five factor mixed design ANOVA. A graphic display of mean differences for the six independent groups is presented in Figure 1. As noted in the table, all main effects were significant but since several interactions were also significant, interpretations in such instances will be given in terms of appropriate simple effects.

There were significant differences in the effects of the three types of instructions only in the free standing condition ($\underline{F}$ $(2,108)_A$ at b_2 = 7.72, $\underline{p} < .001$). A Newman-Keuls comparison indicated that the uncomplicated instructions were superior to both of the dual tasks instructions ($\underline{p}$'s $< .01$). No differences were found in the effects of the three instructions under the wrist restrained condition.

For the free standing condition these findings support the prediction that the imagined stillness task would interfere with the ideomotor effect but they contradict the prediction that the counting backwards task would facilitate the effect. Both types of dual tasks interfered with the ideomotor effect.

The free standing musculature condition produced significantly larger ideomotor effects only under uncomplicated instructions ($\underline{F}$ $(1,54)_B$ at a_2 = 39.41, $\underline{p} < .001$) and under the counting backwards instructions ($\underline{F}$ $(1,54)_B$ at a_3 = 10.89, $\underline{p} < .001$). In other words, free standing produced significantly larger effects than did wrist restrained musculature with the one exception that there was no appreciable difference in the musculature factor for $\underline{S}$s who had been given the concomitant task of imagining stillness of the hand.

These findings indicate that the ideomotor effect would in general be larger when more musculature is available for contributing to the movement in the free standing as compared with the wrist restrained condition. Moreover, the one exception is a reasonable one; it makes sense that the effect of imagined stillness of the hand would be to prevent any appreciable difference between the effects of free standing and wrist restrained musculature.

The uncomplicated significant main effect of the visual imaginal prompt factor (see Table F-value) indicates that ideomotor effects were larger when Ss were given visual prompts than when they were not given them. These findings support the prediction that visual prompts would be a substantial and reliable facilitative influence.

An extensive breakdown of the auditory imaginal prompt factor at treatment combinations of instructions, musculature, and sex indicated that auditory prompts were effective only in the free standing condition for female Ss who had been given either the uncomplicated instructions ($F\ (1,108)_D$ at $a_2b_2e_2 = 32.08$, $p < .001$) or the counting backwards instructions ($F\ (1,108)_D$ at $a_2b_2e_2 = 10.99$, $p < .01$).

In summary, the auditory prompts factor was effective only under a few combinations and levels of other factors. Moreover, auditory prompts accounted for less than one tenth as much reliable variability as did the visual prompts factor ($SS_D SS_C = 21.55/228.94 = .094$). Of course, the auditory prompts factor was involved in interactions and thus, somewhat more reliable variability was associated with it than is revealed by this particular comparison.

These findings support the prediction that auditory prompts would have smaller and less reliable facilitative influences than would visual prompts. Moreover, the lack of a significant interaction between visual and auditory prompts ($\underline{F}\ (1,54)_{CD} = .52$, $\underline{p} > .50$) or of significant higher-order interactions involving their combination is consistent with the prediction that their effects are additive.

A simple main effects analysis of the sex factor indicated that females produced significantly more ideomotor response in the free standing condition than did males; it proved unnecessary to qualify this relationship in terms of the levels of auditory prompts. Thus the prediction that females would produce larger ideomotor effects than would males was supported for the free standing but not for the wrist restrained condition.

The findings regarding the different effects of the visual and auditory imaginal prompts appeared to be most directly related to concerns over the symbolic processes which mediate ideomotor behavior. The hypothesis regarding this finding was that the process of imagined movement and the process of perceived imaginal prompts readily augmented one another since they were in the same perceptual modality. The auditory-verbal prompts, however, likely had to undergo an extra cognitive coding step, requiring a transformation to a visual information form before being readily incorporated into the visual imaginal process. An alternative hypothesis, not ruled out by the present findings, is that the visual prompts, in view of their spatial component, simply represent more information than the auditory-verbal cues; and it is therefore spatial information rather than differential coding in imagery that accounts for the findings.

III. A REFINED EXPERIMENTAL METHOD

The third experiment in the series was designed to explore these alternative hypotheses and make the overall experimental method more precise. Fulfilling these objectives required automating the means of presenting the visual and auditory imaginal prompts. Visual stimulation was designed which consisted of a vertical white line which oscillated horizontally on a TV monitor. Two types of moving auditory stimulation were developed and compared with the visual stimulus. First, an ascending-descending tone (more concrete than the "back-forth" utterances used previously) was developed. The second auditory stimulus was designed with a direct spatial component; a tone appeared to move back and forth through space between S's ears. If this spatial auditory stimulus proved as effective an imaginal prompt as the visual stimulus, the differential coding in imagery hypothesis would not be supported.

Also tested was the effectiveness of the imaginal prompts under conditions where S could either see or not see the actual pendulum motion. If the relations among the prompts remain the same when feedback of results is absent, contentions that our findings are merely attributable to Ss trying to fulfill "good subject roles" (Orne, 1959, 1962, 1969) would be untenable since an S would lack feedback to match expectations regarding E's hypotheses.

Experiment III

Method

Apparatus and Materials. The apparatus and materials were the same as those used in experiments I and II except for three differences. First, a removable board was added which, when in place, occluded sight of the pendulum but not of the visual prompts. Second, Ss were required to wear a heavy leather glove lined with cotton. This was sufficient to reduce sharply or remove reported awareness of kinesthetic afferent feedback. Finally, automated imaginal prompts were exclusively used in this experiment.

The oscillating visual stimulus was a DC voltage sweep generated by an oscillator, displayed on an oscilloscope, and then videotaped and played on a 21" TV monitor. The monitor was placed three feet in front of S tipped at a fifteen degree angle. The vertical white line so generated oscillated horizontally on the TV screen, ten inches from side-to-side.

The first auditory stimulus was an ascending-descending tone (450-850 Hz) presented binaurally through earphones. The second auditory stimulus involved the dichotic presentation of two amplitude modulated tones (500 Hz). The modulation of the tone to one ear was 180 degrees out of phase with the modulation of the tone to the other ear. The perceived impression was that of a single tone moving back and forth, in space, between the ears.

All of the oscillating stimuli were generated sinusoidally and timed to correspond to the exact harmonic period of the pendulum's sinusoidal motion.

Subjects. Eight male and seven female introductory psychology students fulfilling course requirements at the University of New Hampshire served as *S*s.

Procedure. The experimental procedure was identical to that of experiments I and II. A four level imaginal prompts factor (no stimulus, ascending-descending tone, spatial tone, visual stimulus) was crossed with a two-level occlusion factor (pendulum sweeps not visible vs. visible), resulting in eight within *S*s conditions. Three blocks of eight trials each were run with the order of trials within a block randomly determined for each *S*. The three measures for each task were averaged prior to analysis.

Results

The data were analysed by a two factor design ANOVA with repeated measures. No sex differences (main or interactive) emerged in an initial three factor analysis. As can be seen in Figure 2, the pendulum movement was significantly larger when sight of actual pendulum oscillations was permitted. (F (1,14) = 6.33, $p < .05$). All three types of imaginal prompts significantly facilitated the build-up of pendulum motion (F (3,42) = 18.80, $p < .001$). However, a Newman Keuls comparison indicated that the presence of the visual stimulus resulted in significantly larger swings (p's $< .01$) than either of the auditory stimuli. The latter two stimuli did not differ from one another but were each significantly different from the no imaginal prompt condition (p's $< .01$). In contrast to this objective finding, post-experimental questioning of Ss revealed that 8 out of the 15 Ss regarded the spatial tone as the most subjectively compelling and suggestive of movement. The pattern of results which emerged from an analysis of just these eight Ss was not appreciably different from that of the main analysis. Thus, the spatial component added to the auditory stimulus was sufficient to strengthen conscious introspective imagination but did not produce as much objective ideomotor effect as a visual-spatial imaginal prompt.

The lack of a significant interaction between the factors in this study ($F_{AB}(3,42) = 0.78$, $p > .50$) is a noteworthy finding. Although feedback of results is crucial in terms of the overall magnitude of the ideomotor effect, the relationship among the imaginal prompts prevailed independent of feedback. Since sight of the pendulum and proprioceptive finger cues were prevented, a S would have had difficulty simply doing what he thought E wanted him to do. This pattern of findings helps substantiate the contention that the movement of the pendulum is a natural, motoric product of the process of imaginal representation of action.

Discussion

It appears relevant to comment on the subjective quality of the illusory effect of the pendulum's motion. The misperception is likely a consequence of a discrepancy or decorrelation between visual and kinesthetic reafferent feedback (for discussions of decorrelation, see Held, 1965, and Gibson, 1966). Our working interpretation of the pendulum illusion is that covert ideomotor responses are available to the perceptual process when S operates the pendulum, that is, they are theoretically available. However, either the mechanorecptors associated with the afferent nerves of the musculature fail to detect the incipient vibrations, presumably because insufficient energy is available for their activation, or, since the background of awareness is saturation with kinesthetic impressions to begin with, it may be difficult to detect and recognize introspectively specific motor sensations which accompany covert muscle processes. That covert ideomotor responses or information can be made available to awareness by operations of enhancement or amplification, suggests the relative physiological deficiency of the receptors or the inadequacy of introspection in this context.

The results of the first three studies begin to quantify the relationship in the pendulum illusion between imagined activity and the covert muscular expression of that activity. It is clear that the allocation of attention to imagined movement, the amount of musculature available to participate in the covert expression of thoughts of movement, perceived inter-modality imaginal prompts, and visual and kinesthetic reafferent feedback are lawfully related to the pendulum's movement. Sex differences emerged in experiment II but were confounded by the fact that E was male. No sex differences were detected in experiment III. The primary difference between the two experiments was that E became much less involved procedurally in the latter, suggesting that the initial differences between males and females may be attributable to social, interpersonal factors.

One variable not dealt with specifically in these initial studies was the effect of practice or learning on the ideomotor process. While initial pilot studies showed that the magnitude of the pendulum effect increased and then decreased slightly over about thirty trials, an analysis which included blocks as a factor in experiment II indicated that this variable did not result in significant main or interactive effects. Relative to the size of the other effects in experiment II, the effect of blocks was not of sufficient magnitude to be detected. The impression from pilot work remains, however, that strong learning effects would emerge if measures were taken over a much larger number of trials and blocks than was the topic of concern in the present series of studies.

It has previously been mentioned that factors of social pressure, conformity, and demand characteristics would influence the pendulum effect and, indeed, the findings with regard to sex suggest that the pendulum method is suited for the study of the social psychology of the experimental situation. However, the emphasis of the present approach has been on the perceptual/cognitive implications of the phenomenon. It is worth noting in this context that a substantial amount of between subjects variability existed in all three studies reported here. In contrast, within subjects effects--primarily the manipulation of imaginal prompts and reafferent feedback--were highly reliable. It is tempting to speculate that between subjects variability is attributable to social processes (more traditional influence conceptions of suggestibility), whereas the within subjects effects represent components of a cognitive, sensory-motor skill. It will be recalled that support for the interpretation of the pendulum illusion as a skilled performance was found in experiment III where the relation among different imaginal prompts prevailed independent of knowledge of those effects.

In view of this interpretation perhaps the most interesting finding is that visual imaginal prompts resulted in larger facilitative effects than auditory prompts even after deliberate attempts to embellish the latter. One interpretation of this finding is that the auditory prompts were not adequately embellished. The preferred interpretation is that visual images and visual signals may be processed in the same visual channel while auditory images and auditory signals are processed in a separate channel. If this is correct then the presentation of visual prompts which differed from the motion of the pendulum would represent a conflict with imaginal processing in the visual information channel. Conflicting auditory prompts, however, would not result in as much interference since they are processed in a separate information channel. A similar interaction to the one predicted here has been obtained by others within memory (Brooks, 1970; Bower, 1972; Atwood, 1971) and signal detection research contexts (Segal & Fusella, 1970, 1971). If replicated within the ideomotor context, such a finding would help validate the pendulum method as a means of exploring imaginal representation.

This interpretation is offered here merely as a heuristic guide to further steps in the research program, not at this stage as a tightly-documented conclusion.

IV. CONFLICTING IMAGINAL PROMPTS AND THE PENDULUM EFFECT

The next set of experiments was designed to explore further the effects of externally controlled stimulation on the ideomotor process. The basic strategy underlying the two experiments to be reported in this section involved the establishment of incongruities between the actual motion of the pendulum and simultaneously perceived external prompts. In the first experiment a conflict was created by varying the wave forms of the automated oscillating imaginal prompts. In addition to sinusoidal oscillation of auditory and visual prompts, which had been used previously since the motion of a pendulum is inherently sinusoidal, triangle and square wave forms were used to generate the moving stimuli as well. The prediction was that the presence of sinusoidal oscillating stimuli should facilitate the build-up of pendulum motion more than triangular wave forms which in turn should be superior to square wave forms, since these forms contain successively less precise kinetic information, respectively, relative to the sinusoidal motion of the pendulum. Moreover, it was predicted that such an effect would be more pronounced for visual prompts since the perception of different kinds of movement would directly conflict with the perception of sinusoidal pendulum motion and imaginal processing in the visual information channel.

Experiment IV

Method

Apparatus and materials. The apparatus and materials were identical to those used in experiment III, except that the board used to prevent sight of the pendulum was not used. The oscillators used to generate the visual and spatial-auditory imaginal prompts had the facility to produce sine, triangle, and square wave signals.

Subjects. Four male and eight female introductory psychology students fulfilling course requirements at the University of New Hampshire served as *S*s.

Procedure. The procedure was the same as in the first three experiments. Each *S* spent about five minutes practicing under all treatment conditions. The factorial combination of a two level visual prompts factor (absence vs. presence of visual prompts), a two level auditory prompts factor (absence vs. presence of auditory prompts), and a three level wave form factor (square, triangle, and sine waves) resulted in twelve within *S*s conditions. Two blocks of twelve trials each were run with the order of trials within a block randomly determined for each *S*. The two measures of pendulum movement for each task were averaged prior to analysis.

Results

The data were analysed by a three factor design ANOVA with repeated measures. The mean differences among all treatment conditions are graphically presented in Figure

3. The presence of auditory imaginal prompts significantly facilitated the build-up of pendulum motion (F (1,11) = 11.83, $p < .01$). The presence of visual imaginal prompts also resulted in a significant main effect (F (1,11) = 10.16, $p < .01$) but this effect was qualified by a significant visual prompt-X-wave form interaction (F (2.22) = 11.94, $p < .001$). The significant main effect of the wave form factor (F (2,22) = 9.80, $p < .001$) was also qualified by this interaction. In general, however, a Newman-Keuls comparison indicated that the sine, triangle, and square wave forms were significantly different from one another (p's $< .05$). The sine wave was most facilitative followed by the triangle and square waves in that order.

Due to the significant visual prompt-X-wave forms interaction further interpretations will be given in terms of simple main effects analyses. This interaction is graphically depicted in Figure 4. Regarding the visual prompt factor, it was determined that the presence of the visual square wave stimulus did not result in a significant facilitory effect, while the presence of the visual triangle wave stimulus (F (1,33) = 12.99, $p < .01$) and the visual sine wave stimulus (F (1,33) = 19.19, $p < .001$) did result in significant effects. The effect of wave form type turned out to be significant only when visual imaginal prompts were present (F (2,44) = 19.96, $p < .001$). A Newman-Keuls comparison of different wave forms when visual prompts were present indicated that the sine, triangle, and square wave forms were significantly different from one another ($\underline{p}$'s $< .05$). The sine wave was most facilitative followed by the triangle and square wave forms in that order.

The results indicate that the average amount of pendulum movement increased significantly as the wave form underlying the imaginal prompts successively approximated the form of actual pendulum motion, except when visual prompts were absent. The auditory prompts alone evidently do not exert sufficient effects on visual imaginal processing to allow the distinction in wave forms to emerge. When auditory prompts were absent the visual imaginal prompts were strong enough to allow the facilitative difference between wave forms to emerge. Although visual stimulation in general resulted in a significant main effect, it is not facilitative when generated by a square wave. Evidently, the discrete back and forth switching of the visual square wave stimulus when encoded interferes with continuous visual imaginal processing. In contrast the discrete metranome-like cadence of the auditory square wave does not exert interfering effects.

Even though the imaginal prompts used in this study differed from actual pendulum motion, they did not present a strong conflict since the frequency of the moving stimuli was still the same as the frequency of pendulum motion. Therefore, the next experiment was designed which set the frequencies of pendulum motion and imaginal prompts in opposition.

Experiment V

In the fifth experiment of the series the tempo of an oscillating pendulum was varied relative to the tempo of the imaginal prompts. Subjects suspended five different length pendulums and imagined the back and forth movement of each. Presumably, when a S suspends and imagines the movement of a long pendulum, the tempo of his imagination is relatively slow due to the low frequency of longer pendulum. While imagining the movement of a given pendulum, Ss perceived a single fixed oscillating stimulus which had a period corresponding to only the intermediate-length pendulum. As S imagines the slow back and forth movement of a long pendulum and at the same time perceives a relatively faster moving standard imaginal prompt, the tempo of imagined movement and the tempo of perceived movement would be incongruous, resulting in an attenuated ideomotor effect. The same argument, in reverse, applies to the imagined movement of short pendulums which have high frequencies relative to the standard frequency of the imaginal prompt. The prediction then was that the ideomotor movement of the pendulum would be larges when the tempo of imagined and perceived movement were the same and would decrease as the discrepancy between the two increased. Again, it was also predicted that this relationship would be more pronounced for visual imaginal prompts due to competition between perceptual and imaginal processing in the visual information channel.

Method

Apparatus and materials. The apparatus and materials were identical to those used in experiment IV, except that five different length pendulums were suspended by S. In addition to the standard 24 inch length, pendulums of 16, 20, 28, and 32 inches in length were also used. The resonant frequencies of the five pendulums' movement were .79, .69, .64, .59, and .55 Hz respectively. The spatial-auditory and visual imaginal prompts were timed to correspond only to the resonant frequency of the 24 inch pendulum (.64 Hz).

Subjects. Ten male and ten female introductory psychology students fulfilling course requirements at the University of New Hampshire served as Ss.

Procedure. The procedure was essentially the same as that of previous experiments. After the introduction to the experimental session S spent about five minutes practicing with the 16, 24, and 32 inch pendulums when auditory and/or visual stimulation was present and absent. The factorial combination of a two level visual prompts factor (absence vs. presence of visual prompts), a two level auditory prompts factor (absence vs. presence of auditory prompts), and a five level pendulum length factor (16, 20, 24, 28, and 32 inches) resulted in twenty within Ss conditions. One block of trials was run with the order of trials within a block randomly determined for each S.

Results

The results were analyzed by means of a three factor design ANOVA with repeated measures. The mean differences among all treatment conditions are graphically presented in Figure 5. Significant main effects emerged for the pendulum length factor (F (4,76) = 5.56, $p < .001$) and the visual imaginal prompt factor (F (1,19) = 19.51, $p < .001$). However, a significant interaction between these two factors (F (4,76) = 2.59, $p < .05$) qualified their interpretations. The effect of the auditory prompt factor was not significant.

Due to the significant visual prompt-X-pendulum length interaction interpretations will be given in terms of simple main effect analyses. Figure 6 graphically depicts this interaction. The presence of visual prompts resulted in significant effects for the 16 inch pendulum (F (1,95) = 8.01, $p < .01$), the 20 inch pendulum (F (1,95) = 4.26, $p < .05$), the 24 inch pendulum (F (1,95) = 23.77, $p < .001$), and the 32 inch pendulum (F (1,95) = 5.59, $p < .01$). Visual prompts were not significant when the 28 inch pendulum was in use (F (1,95) = .82, $p > .50$).

The effect of pendulum length was significant both when visual prompts were absent (F (4,152) = 2.92, $p < .05$) and when visual prompts were present (F (4,152) = 6.57, $p < .001$). However, a Newman-Keuls comparison of the effects of different length pendulums when no visual prompts were present indicated that only the movement of the 28 and 32 inch pendulums differed significantly ($p < .05$). In contrast, when visual prompts were present, the 24 inch pendulum resulted in significantly more movement than each of the other pendulums (p's $< .05$).

In order to replicate an interesting finding of experiment III, Ss were questioned after the experiment regarding their subjective experiences. Eleven out of the twenty Ss reported that when the pendulum motion and imaginal prompts where congruous the auditory stimulus was more compelling and allowed them to construct better imaginal representations of movement. A reanalysis of just these eleven Ss showed no appreciable difference in the pattern of results from the main analysis. Objectively, when the pendulum motion and imaginal prompts were congruous, visual prompts exerted the stronger effect, a finding which is inconsistent with subjective reports.

In general the results from experiment V indicate that when visual prompts were absent incongruous auditory prompts did not exert sufficient influence on visual imagination to allow the response gradient about the 24 inch pendulum to emerge. When incongruous visual prompts were present, however, a clear, sloped response gradient emerged. As the frequency of the oscillating pendulums diverged from the fixed visual imaginal prompt, the extent of pendulum movement decreased due to the conflict created when different frequencies of movement are simultaneously processed in the visual information channel.

Discussion

The results of these two studies are strikingly similar and support the theoretical predictions made in the previous quantification section. When a S imagines pendular movement and simultaneously perceives external stimulation which differs along certain parameters from actual pendulum motion, the process of visual imagination is curtailed, resulting in an attenuated ideomotor effect. The perception of incongruous auditory prompts, however, does not exert interfering effects of a comparable magnitude. As mentioned earlier, it is hypothesized that this is due to the less dominant effect of auditory information on the process of visual imagination in general. Visual imaginal prompts, when compatible with imagined activity, strongly facilitate the build-up of pendulum motion, but as they become less compatible their facilitative effect vanishes, presumably due to a conflict of processing in the visual information channel. Since auditory information would be processed in a separate channel no direct, intra-modal conflict would exist. The upshot of these findings is that seeing and imagining employ similar--perhaps the same--mechanisms.

These two studies demonstrate that the facilitative effect of imaginal prompts can be degraded, although incongruous imaginal prompts of the type used here still facilitate the build-up of pendulum motion relative to a no imaginal prompt condition. Evidently the perception of any kind of movement (at least within the parametric limits established in these studies) seems to help _S_s imagine movement. The next related set of questions asked in the investigation centered around the relation between the perception of moving, electrical-analog reafferent feedback and the process of imagined activity.

V. ANALOG REAFFERENT FEEDBACK AND THE PENDULUM EFFECT

William James stated at the end of the nineteenth century that a mental image of the sensory consequences of an act was sufficient to awaken in some degree the actual movements constituting the act (James, 1890, II). While the external stimuli used in the experiments to this point as imaginal prompts approximated the sensory consequences of a pendulum's motion, they were not contingent on S's behavior and resultant pendulum motion. It was decided, therefore, to explore specifically the effects of electrical analog reafferent feedback on the ideomotor process.

A special electronically-monitored pendulum producing visual or auditory analog feedback was designed. The first question asked was whether the presence of augmented feedback would facilitate the build-up of pendulum motion. It had previously been demonstrated (experiment III) that sight of actual pendulum motion increased the magnitude of the pendulum effect. Could the effect be increased even further by supplying still additional feedback information? The effect of visual and auditory analog feedback was assessed both when the pendulum oscillations were visible and not visible.

Experiment VI

Method

Apparatus and materials. The apparatus and materials were the same as those used in previous experiments except that a special pendulum was used. The pendulum consisted of a hand grip with an attached frictionless potentiometer. Affixed to the potentiometer was a 24 inch, stiff wire (3/16 inch dia.) with a three ounce weighted film canister at its end. As in previous experiments the pendulum, when in use, was held in front of the black backboard. A removable board was again used which, when in place, prevented sight of the pendulum oscillations but not of the visual feedback.

Any sinusoidal movement of the pendulum (restricted to one dimension due to the stiffness of the wire) was converted by the potentiometer to an electrical signal. The visual feedback consisted of the signal displayed directly as a DC voltage sweep on an oscilloscope, which in turn was videotaped and played on the TV monitor as a vertically oscillating white line. The gain of the oscilloscope was adjusted so that the vertical, spatial displacement of the DC feedback signal was the same as that of the actual pendulum oscillation.

The electrical signal generated by the pendulum potentiometer also acted as a modulating signal for the auditory feedback which was presented dichotically through earphones. When the pendulum was at rest S heard a tone in each ear of equal amplitude. Any movement of the pendulum amplitude modulated the tones. The modulation of the tone to one ear, however, was 180 degrees out of phase with the modulation of the tone to the other ear. The perceived impression was that of a single tone moving laterally wider and wider between S's ears as the pendulum arc widened. The gain of the modulating circuit was adjusted so that even very small movements of the pendulum (observable visually) resulted in a "movement" of the tone.

Subjects. Seven male and seven female introductory psychology students fulfilling course requirements at the University of New Hampshire served as Ss.

Procedure. The procedure and instructions to Ss was essentially the same as in previous experiments. Ss spent about five minutes practicing with the special pendulum first without the feedback and then with the addition of the feedback. Ss were shown that the visual and auditory feedback was perfectly correlated with pendulum motion and could be used to strengthen or guide their imaginal constructions. Subjects practiced using the feedback under conditions where the pendulum was visible or not visible. The factorial combination of a two level occlusion factor (pendulum not visible vs. visible), a two level visual feedback factor (absence vs. presence of visual feedback), and a two level auditory feedback factor (absence vs. presence of auditory feedback) resulted in eight within Ss conditions. Two blocks of trials were run with the order of trials within a block randomly determined for each S. The two measures of pendulum movement for each task were averaged prior to analysis.

Results

The results were analyzed by means of a three factor design ANOVA with repeated measures. The mean differences among all treatment conditions are presented in Figure 7. All factors resulted in significant main effects. The pendulum moved more when its oscillations were visible (F (1,13) = 19.05, $p < .001$), when visual analog feedback was present (F (1,13) = 5.76, $p < .05$), and when auditory analog feedback was present (F (1,13) = 5.48, $p < .05$).

These findings were somewhat qualified by an interaction between the three factors which, while not reaching conventional levels of significance, was significant at the .10 level (F (1,13) = 4.52, $p < .10$). Simple main effect analyses indicated that the occlusion factor was significant when no analog feedback was present (F (1,13) =16.59, $p < .01$), when visual feedback only was present (F (1,13) = 5.76, $p < .05$), and when both visual and auditory feedback were present (F (1,13) = 11.77, $p < .01$). The effect of visual feedback was significant only when (1) the pendulum was not visible and auditory feedback was not present (F (1,13) = 8.17, $p < .05$), and (2) the pendulum was visible and auditory feedback was present (F (1,13) = 7.60, $p < .05$). Correspondingly, the effect of auditory feedback was significant only when (1) the pendulum was not visible and visual feedback was not present (F (1,13) = 8.18, $p < .01$), and (2) the pendulum was visible and visual feedback was present (F $(1,13) = 4.67$, $p < .01$).

While these findings appear complicated, they are interpretable once it is recognized that the visual and auditory analog feedback in this experiment was totally redundant with actual pendulum motion feedback. All three types of feedback could be used to strengthen imaginal constructions of movement. Indeed the marginally significant interaction seems to suggest that one kind of feedback often can substitute for the other. When the pendulum could not be seen, either the visual or auditory feedback alone facilitated the ideomotor process. The two types of feedback presented together without sight of the pendulum added nothing more to the expressive process than either prompt alone. When the pendulum was visible, on the other hand, facilitation resulted only when both visual and auditory feedback were presented together. The sight of the pendulum oscillations was apparently adequate until the augmentation of feedback reached a higher level.

In general, the findings indicate that Ss can use the additional analog feedback to guide their imaginal constructions of movement. Facilitative effects will not necessarily emerge, however, if sufficient information already exists. Thus, not only does an image of the sensory consequences of an act awaken in some degree the actual movements of the act, but the perception of augmented sensory consequences does so as well. The perception of the feedback (or the imaginal prompts of the previous experiments) could logically result in covert movements directly or through the strengthening of an image. The former implies that some sort of imitative encoding of stimuli or feedback is taking place perceptually. While the present experiments did not address this issue directly, more will be said later about the possible relation in the pendulum effect between imitation or modeling and mental imagery.

Within the present context, in order to investigate more precisely the relation between the imagination of movement and the concurrent perception of the consequences of that internal processing, it was decided to delay the feedback. The disturbing effects of delayed sensory feedback on the integrated performance of various types of behavior has been repeatedly demonstrated (Smith, 1962; Annett, 1969). The experimental delay of feedback signals has provided a successful approach to the study of perceptual-motor integration. It was reasoned, therefore, that the interruption of the regulatory processes of ideomotor movement would allow insights into the nature of the underlying representational and sensori-motor mechanisms.

Visual and auditory analog feedback was time-delayed to provide systematic phase shifts of the feedback relative to the actual motion of the pendulum. It was hypothesized that as the degree of phase shift increases Ss should have increasing difficulty imagining a back and forth movement in phase with actual pendulum motion. It was predicted that the effect of covert excitatory movements not in or near the resonant frequency of the pendulum would attenuate the resonant energy of the system, resulting in a decreased ideomotor effect. An interaction between information modality and degree of phase shift was also predicted on the hypothesis that visual signals and images are processed in a different information channel than auditory signals and images. Visual feedback out of phase with actual pendulum motion would represent a conflict with imaginal processing in the visual information channel. Conflicting auditory feedback, however, would not result in as much interference since it would be processed in a different channel.

The effect of the delayed feedback was tested either when the pendulum was visible or not visible. Also tested in this study was the effect of receiving first a block of trials where sight of the pendulum was prevented but the automated feedback was present, compared to receiving first a block of trials where sight of the pendulum motion and automated feedback were both available. Since Ss were not informed in advance that the feedback would be delayed, those first receiving trials with sight of the pendulum allowed would be aware of the conflict situation and perhaps could learn to make mental transformations needed to avoid the disruptive effect of the decorrelated feedback when subsequently performing the block of trials without sight of the pendulum. On the other hand, Smith (1962) reports very little or no learning when perceptual-motor tasks are performed under conditions of delayed feedback. If the pendulum effect can be likened to a skilled performance, perhaps adaptation to the disruptive circumstances will prove very difficult.

Experiment VII

Method

Apparatus and materials. The apparatus and materials were the same as those used in experiment VI. In addition, electronic circuitry (essentially an inverting operational amplifier and a RC circuit) was designed to time delay the feedback relative to actual pendulum motion (0, 45, 180, and 225 degrees).

Subjects. Fifteen male and fifteen female introductory psychology students fulfilling course requirements at the University of New Hampshire served as Ss.

Procedure. The procedure was essentially the same as in experiment VI. Subjects practiced with the special pendulum first without and then with the presence of visual and/or auditory feedback. They were shown that such information was perfectly correlated with pendulum motion and could be used to strengthen their imaginal constructions of movement. Subjects never practiced with the delayed feedback nor were they informed that it would sometimes be delayed during the experimental trials.

All Ss performed sixteen trials representing the factorial combination of three within Ss factors; a two level occlusion factor (pendulum not visible vs. visible), a two level feedback modality factor (visual vs. auditory), and a four level feedback phase shift factor (0, 45, 180, and 225 degrees). One group of 15 Ss first performed a block of eight trials under conditions where the pendulum was not visible. A second group of fifteen Ss first performed a block of eight trials where the pendulum was visible. Each group then transferred to the remaining block of eight trials. The order of trials within a block was randomly determined. Males and females were randomly assigned to the two independent groups.

Results

The data were analyzed by means of a four factor mixed design ANOVA. Significant main effects emerged for the occlusion factor (F (1,28) = 10.80, $p < .01$) and the feedback phase shift factor (F (3,84) = 5.13, $p < .01$). The interpretation of these effects, however, was qualified by a significant occlusion-X-order of occlusion trials interaction (F (1,28) = 7.59, $p < .05$) and a significant feedback modality-X-feedback phase shift interaction (F (3,84) = 3.49, $p < .05$).

As can be seen in Figure 8, the simple main effects analysis of the feedback modality factor indicated that the presence of visual feedback resulted in significantly less pendulum movement than auditory feedback only under the 225 degrees delay condition (F (1,112) = 4.70, $p < .05$). The simple main effects analysis of the feedback phase shift factor indicated that the different delays were significant only for visual feedback (F (3,168) = 8.60, $p < .001$). A Newman-Keuls comparison of the different delays of visual feedback indicated that perfectly correlated feedback resulted in significantly more pendulum movement than each of the other delay conditions (p's $< .01$).

These results support the predicted interaction between feedback modality and the degree of feedback delay. As the phase shift (degree of conflict between feedback and actual pendulum motion) of visual feedback increased, the magnitude of pendulum oscillations decreased. While auditory feedback was comparable in its effect to visual feedback when no conflict was present, it failed to exert significant disruptive effects as the phase shifts increased.

As can be seen in Figure 9, a simple main effects analysis indicated that the effect of pendulum occlusion (more pendulum movement when pendulum oscillations were visible) was restricted to the group of Ss who first performed occlusion trials (F (1,28) = 18.23, $p < .001$). A simple main effects analysis of order of occlusion trials indicated that those Ss performing the occlusion trials first produced significantly more pendulum movement only when the pendulum was visible (F (1,56) = 7.13, $p < .01$).

The first thing to be noted in these results is that those Ss who were aware of the conflicting nature of the feedback (no occlusion trials first) gained little from this treatment which could be used when they were later transferred to the occlusion trials. Adaptation effects perhaps could emerge in the ideomotor process, however, if practice under delayed feedback conditions was assessed over longer intervals of time.

The surprising finding was that Ss transferring from the occlusion conditions produced substantially more ideomotor movement when they subsequently could see the pendulum than those Ss who performed under the no occlusion conditions first. While this finding was not anticipated, more will be said about one possible explanation in the discussion section.

Discussion

In both experiments VI and VII the auditory analog feedback facilitated the ideomotor process almost as much as visual analog feedback. This finding is somewhat at odds with the findings from experiments using imaginal prompts where visual signals were found to exert a stronger facilitative influence. Insufficient data exists at present to determine whether this is attributable to a fundamental difference between feedback and externally controlled signals on the ideomotor process or whether the auditory analog feedback was technically superior to the auditory imaginal prompts. The findings in experiment VII showing that delayed auditory feedback did not exert strong interfering effects on the ideomotor process tend to argue against the latter interpretation. Moreover, as mentioned earlier, the analog feedback was completely redundant with pendulum motion while the imaginal prompts were not.

In spite of these differences, the interaction in experiment VII between feedback modality and feedback phase shifts lends support to the two-channel hypothesis of processing visual and auditory information. The processing of delayed visual feedback conflicts with imaginal processing in the visual information channel making it difficult for Ss to continue to imagine a rate of movement in phase with actual pendulum motion. Delayed auditory feedback would be processed in a separate channel and no direct intra-modal conflict would exist.

The phase shift values used in this experiment were chosen primarily on the basis of the ease of constructing the appropriate electronic circuitry. It would be most useful to obtain data on phase shifts all along the continuum between 0 and 360 degrees (note that a 360 degree phase shift is exactly comparable to a 0 degree phase shift). Certain values would be more critical than others since predictions based on the physical principles of the pendulum can be generated for these. One prediction is that a 90 degree phase lag and a 270 degree phase lag (90 degree phase lead) should effect the ideomotor process to the same extent. Since the pendulum is a simple (single degree of freedom) oscillatory system, there is no a priori reason to expect that excitatory movements 90 degrees behind or ahead of actual pendulum motion should effect the resonant energy of the system differently. Also, it would be predicted that as the degree of phase shift approached 360 degrees, the extent of pendulum motion should gradually increase since the degree of conflicting processing would decrease. In Figure 8 the extended dotted lines represent these hypothesized trends. Obtaining these data experimentally is important since the resulting curves would help elucidate the mechanics of the oscillating pendulum interacting with excitatory bodily musculature.

The most surprising finding in the experiment was that _S_s transferred from occlusion conditions produced substantially more ideomotor movement when they could see the pendulum than _S_s who performed under no occlusion conditions first. One possible explanation which is consistent with the viewpoint that the pendulum effect involves a cognitive skill is that _S_s performing without sight of the pendulum are forced to attend to proprioceptive feedback from the hand and arm. A rate of movement based primarily on proprioceptive information would be constructed and learned imaginally. The learning would manifest itself on subsequent no occlusion trials when the sight of the pendulum oscillations could verify and augment the proprioceptively based kinetic image. Subjects who performed under no occlusion trials first may have relied too heavily on the sight of pendulum oscillations. The visual feedback of actual pendulum oscillations may have been too good an indicator in the sense that _S_s attended to it to the detriment of attending to proprioceptive feedback.

Those Ss performing without sight of the pendulum first were, therefore, in a better position to learn something about the feel of the correct rate which was all they could rely on since the visual and auditory feedback was delayed and misleading. Lincoln (1954, 1956) found analogous results when he required Ss to produce a given rate of movement by turning a handwheel under discrete verbal error feedback conditions or under continuous visual analog feedback conditions. Subjects who learned the rate of movement with the aid of visual feedback learned rapidly but, when the feedback was removed on criterion trials, their performance deteriorated far further than the Ss under verbal error feedback conditions.

One is reminded by the results from the present experiment of William James' assertion that an image of the sensory consequences of an act awaken in some degree the actual movements constituting the act. Certainly a kinetic image based on proprioceptive as well as visual feedback approximates more closely the sensory consequences of a moving pendulum suspended by the fingers. Presumably those Ss transferring from conditions without sight of the pendulum to conditions with sight of the pendulum would construct images based on proprioceptive and visual feedback of pendulum oscillations. The composite image may be a superior symbolic representation as indexed by the magnitude of ideomotor movement of the pendulum.

A direct empirical verification of this hypothesis has not been performed. However, a different perspective on the present data is revealing and loosely supports the above argument. If a proprioceptively learned rate of movement is the critical factor underlying the results of this experiment, then Ss who produce more pendulum movement in general should be in a better position to construct a suitable image simply because more proprioceptive information is available. One would expect Ss under occlusion conditions who produce substantial ideomotor movement initially to improve more when transferred to no occlusion conditions than Ss who do not produce as much pendulum movement initially.

The obtained pendulum occlusion-X-order of occlusion trials interaction was reevaluated with the addition of a third factor. Five Ss who produced the most pendulum movement and five Ss who produced the least pendulum movement were selected from each independent group. Presumably these Ss differed in terms of the amount of proprioceptive feedback available to them. The mean differences among these treatment combinations are presented in Figure 10. The data were not treated statistically due to the inadequacy of the present approach as a critical test of the proprioceptive imagery hypothesis. The results are only suggestive. The impression is, however, that Ss producing large amounts of pendulum motion when first performing under occlusion conditions improve much more when transferred to no occlusion conditions than Ss of the same group who produce very little pendulum motion. The working interpretation is that a kinetic image of a rate of movement with a strong proprioceptive component is actualized in covert behavior more readily than a kinetic image based more predominantly on visual information.

Of course, one could claim that Ss producing more movement initially were more "suggestible" and more sensitive to the changed experimental circumstances (i.e., a board was removed and the pendulum became visible). These Ss it might be argued simply went along with E, assuming he expected them to move the pendulum more. However, one must then explain why Ss who produce large pendulum motion and transfer from no occlusion to occlusion conditions do not display a corresponding decrease in ideomotor responsiveness due to the changed experimental circumstances (i.e., a board was set in place the pendulum was no longer visible). Certainly the present *post hoc* analysis will not settle the issue. Another investigation designed with appropriate controls is needed. The influence of proprioceptive feedback on the ideomotor process is likely quite substantial and should be explored more fully.

VI. SUMMARY AND CONCLUSIONS

Seven experiments were performed to quantify the Chevreul pendulum effect and develop a valid method for the study of nonverbal representation. The first three experiments isolated several parameters of the pendulum effect. Findings indicated that the deployment of cognitive resources, the amount of musculature free to participate in the covert expression process, the presence of visual reafferent feedback, and the presence of visual and auditory oscillating imaginal prompts reliably influenced the extent of pendulum motion.

A second set of experiments dealing specifically with the effects of externally controlled stimulation on the ideomotor process utilized incongruities between actual pendulum motion and simultaneously perceived electronically automated imaginal prompts. Findings were (1) that visual and auditory imaginal prompts were facilitative only when they were congruous with imagined activity and the accompanying pendulum motion, and (2) that visual prompts exerted a dominant effect relative to auditory prompts; depending on the degree of conflict, visual prompts facilitated or disrupted the ideomotor process more than did auditory prompts.

A final set of experiments was designed to explore the effects of automated visual and auditory reafferent feedback on the ideomotor process. The addition of augmented feedback was found to facilitate the buildup of pendulum motion. The experimental delay of the visual and auditory feedback produced analogous results to those obtained for conflicting imaginal prompts. Visual feedback was found to exert a dominant effect on the ideomotor process. Some unexpected evidence emerged which suggested the possible importance of proprioceptive feedback in the pendulum effect.

Theoretically, the pendulum illusion has been conceptualized as involving a cognitive skill. The movement of the pendulum should not be regarded as merely representing some kind of obligation or heightened inclination to respond to influences which operate outside the bounds of voluntary compliance. The skill involved in creating the pendulum illusion entails a cognitive ability for voluntarily implementing one's imagination in an organismically coordinated way. If only it is not suppressed or inhibited, the movement of the pendulum will occur as a natural motoric by-product of imaginal activity.

A variety of implications emerged from the data which support the interpretation of the pendulum illusion as a skilled performance. First, the analysis of these experiments revealed the existence of a substantial amount of between _S_s variability. In contrast, within _S_s effects--primarily the manipulation of imaginal prompts and reafferent feedback--were highly reliable. As mentioned previously, it is tempting to speculate that between _S_s variability is attributable to social processes (more traditional influence conceptions of suggestibility), whereas the within _S_s effects represent components of a cognitive, sensory motor skill. One could argue, on the other hand, that within _S_s conditions were arranged so that cues regarding _E_'s hypotheses were salient and allowed all _S_s to produce a similar, covarying profile of results across repeated measure trials. In other words, demand characteristics (Orne, 1959, 1962, 1969) were spuriously responsible for the within _S_s effects.

Several lines of reasoning suggest that this was not the case. Trials within blocks of repeated measures were randomized eliminating the chance that _S_s could discern an overall pattern based on a fixed order of trials and transfer between trials. Interactions were also predicted between variables and were supported. It is not obvious that _S_s are readily capable of discerning and conforming to predicted interactions. Most significantly, support for the interpretion of the pendulum illusion as a skilled performance was found in experiment III where the relation among different imaginal prompts (within _S_s effects) prevailed independent of _S_s knowledge of those effects.

Experiments III and V yielded additional data which bear on this issue. It will be recalled that in both experiments over half of the _S_s reported that the spatial auditory stimulus was more subjectively compelling and allowed them to construct better imaginal representations of movement than did the visual stimulus. These introspective reports, however, were in direct contradiction to objective findings which indicated that the greatest pendulum movement occurred when the visual stimulus was present. These S's objective performance failed to confirm their own introspective reports making it difficult to believe that they were able to conform rather precisely to E's hypotheses.

It seems implausible then, that the results of these experiments are merely attributable to demand characteristics. Of course a more direct empirical test than performed here would be useful. A possibility would be to repeat the occlusion conditions of experiment III and ask Ss to deliberately try to produce the exact magnitudes of pendulum movement which emerged in that experiment when sight of the pendulum was prevented. If they could not do so under the impoverished feedback conditions, a demand characteristic interpretation of the results would not be supported.

A common logic connecting these three sets of experiments is a theoretical concern over the process of imaginal representation and its relation to perception. These experiments are in part concerned with the parameters of stimuli which are encoded and symbolized in imagination. Early in the investigations it became clear that the type of internal representations constructed by Ss were not necessarily vivid or pictorial in nature and thus, were not amenable to introspective analysis. Some Ss were aware of clear picture-like images. Others were aware of only vague symbolic representations and a few Ss reported only imageless thoughts of movement. While Paivio (1971) reports that vividness of mental imagery is the most reliable predictor of recall in paired associate learning tasks, Neisser (1972) has demonstrated empirically that mental imagery ratings are not reliable predictors of recall, since imagery is not necessarily pictorial in nature. In order to be effective, only the schematic, invariant relations of the stimulus world need be represented imaginally (Attneave, 1972; Pylyshyn, 1973).

In view of this controversy over the nature of mental imagery, it was decided to investigate the relation between S's reported vividness of imagery and the objective ideomotor movement of the pendulum. A shortened form of the Betts Questionnaire Upon Mental Imagery (Sheehan, 1967) was administered to Ss prior to experiment V. Also, Richardson's revised form of the Gordon test of controlability of imagery (Richardson, 1969) was administered. The various scores on the questionnaires were correlated with Ss subsequent pendulum movement under all treatment conditions of experiment V. These results were not reported in the main section because reliable findings failed to emerge. No reported vividness ratings (within or across seven sense modalities) or the reported controlability of imagery scores correlated significantly with the magnitude of the ideomotor movement of the pendulum. Evidently reported vividness or controlability of mental imagery is not a primary factor underlying the extent of pendulum movement. Some other conception of the nature of mental imagery, at least for ideomotor phenomena, is needed.

Within the Chevreul pendulum context it has been previously suggested that there may be a very close relationship between mental imagery and imitation. It is tentatively proposed that the facilitative and disruptive effects of imaginal prompts and augmented feedback may be attributable to a symbolic modeling of the observed signal which interacts with the process of mental imagery. In fact, the distinction betwe the two processes may be that the latter occurs independent of an observed external signal. The imitative encoding of moving stimuli and the imaginal construction of movement may share common mechanisms. Various theorists have suggested that perceptual inputs are encoded in terms of images or response codes which are essentially covert acts of replication (MacKay, 1951; Piaget, 1951; Miller, Galenter & Pribram, 1960). In fact, for Piaget the representational image is a draft of potential imitation and therefore the product of the interiorization of imitation (Piaget & Inhelder, 1971).

The importance of imitation as a learning phenomenon has received recent attention after it had been virtually ignored by American psychologists for the past fifty years. Many writers have criticized traditional associative and reinforcement theories of modeling as accounts unable to explain how a novel matching response is acquired observationally in the first place (Piaget, 1951; Church, 1961, Aronfreed, 1969, Bandura, 1971). The acquisition must occur through symbolic processing during the period of exposure to modeling stimuli, prior to overt responding or the appearance of any reinforcing events. Moreover, imitatively-acquired behavior can later be performed in the absence of a model or observable discriminative stimulus. Clearly, processes of attention, internal representation, and motor production (or reproduction) need to be explored in relation to imitation. Yet most research to date has centered around the effects of children observing the contingencies between the behavior of adult or child models and reinforcement (Aronfreed, 1969). The criteria in these studies for assessing whether subsequent responses by an observer are imitative are generally quite gross. Little attention is paid to the structural fidelity of an observer's modeled behavior. This is a critical point because behavior judged to be grossly imitative may not be at all in the strict sense of cognitive constructions of integrated response codes or images capable of guiding and controlling future actions.

Although the experiments reported here do not represent the necessary tests to establish in ideomotor phenomena the relation between mental imagery and imitation, it would seemingly be possible to do so. In very general terms, one could electrically monitor, amplify, and record incipient eye movements and hand movements which occur when the pendulum is suspended and its movement is imagined. The parameters of these periodic movements could then be compared to those of the pendulum's actual motion, the movement of the imaginal prompts, and the movement of the analog feedback. Data obtained when conflicting imaginal prompts and feedback were present would be most informative. One would expect a decreased magnitude of pendulum motion to be accompanied by eye movement and hand movement records which converge parametrically to the conflicting signals and diverge from the actual pendulum motion.

To this point the investigations have been restricted to the ideomotor movement of the pendulum and, in that sense, the theoretical position emerging from the findings lacks generalizability. The research at this point could be pursued in one of two directions. First, as suggested above, experiments aimed at exploring further the ideomotor action of the pendulum and the internal events that mediate such a response could continue. An equally-appropriate course, however, would be to extend the investigations to other examples of ideomotor behavior, and manipulate the same independent variables described in the present experiments. For example, the effects of moving visual and auditory stimuli on the magnitude of postural sway could be assessed. If their effects proved to be predictable on the basis of the two-channel hypothesis for processing visual and auditory information, continued used of ideomotor phenomena as a means of exploring imaginal representation would be further warranted.

It should be recognized when looking at other examples of ideomotor action that the many means of exploring such behavior--postural sway, arm movement, hand press, hand release, divining rod, ouija board, automatic writing devices, and turning tables--vary in terms of allowing the consistent manifestations of ideomotor behavior. Presumably, this is due to the naturalness of the movement involved and the resulting degree of unconscious compliance or lack of suppression that is required by an individual. The periodic motion of the pendulum is perhaps the most natural because our life is filled with experienced periodic, and indeed, sinusoidal forces--i.e., swinging, rocking, etc. As a result it is quite easy for most people to create illusory pendulum motion by imagining or covertly imitating movement. Similarly, body sway, arm movement, and hand pressing are natural behaviors which we perform automatically day after day as parts of more molar behavior patterns. The ouija board or automatic writing devices, however, require more "belief" or expectation, or compliance to perform in a subjectively compelling manner. Their movement does not appear to be quite as natural a consequence of imagination alone. Since the intent of the proposed future studies is to add to an understanding of the cognitive processes underlying ideomotor behavior, it would be better initially to study those examples that can be performed by most people and involve a minimum of influence commands, exhortation, etc. If the manipulation of the deployment of attention, imaginal prompts and analog feedback prove to have similar effects on phenomena other than the Chevreul pendulum, then the information-processing interpretation of ideomotor movement and suggestibility espoused here would acquire greater generalizability and utility.

A Final Overview

At the end of the nineteenth century the construct of ideomotor behavior was widely invoked to explain tendencies of ideas of action to become actualized in behavior automatically. In short, ideomotor action was conceptually viewed as resulting from an idea striving for motoric realization. The principle first emerged to account for early eighteenth and nineteenth century hypnotic and spiritualistic phenomena. However, William James and William Carpenter, among others, recognized at the turn of this century that ideomotor action actually held special significance for mental functioning in general. Nevertheless, the phenomenon only became seen as a central issue in theories of suggestion and hypnosis, leaving the parameters of ideomotor behavior unstudied. The principle fell into disrepute within general experimental psychology primarily as a consequence of attacks by the American behaviorists (Thorndike, 1913; Watson, 1930). The psychological concept of an idea was not respectable within a rigorous behavior theory system. Recently the emergence of modern cognitive psychology and its methods has changed this dogma and the concept of an image or idea has regained respectability (Sheehan, 1972). An image, doubtless in oversimplified terms, has come to be regarded as a symbolic representation often accompanied by motoric expression. It is not just a direct continuation of sensation and perception. As a result of this entire series of historic developments, a reinterpretation of the principle of ideomotor behavior within an information-processing framework was clearly warranted.

The Chevreul pendulum was chosen to begin a program of research on these matters since it readily allowed the emergence of ideomotor behavior in most people and the effect could be precisely measured. The magnitude of pendulum oscillations was found to be sensitive to specific parameters of periodic covert muscle responses. The methods designed to analyze the topography of those covert muscle responses provided clues to the organization of accompanying internal processes. The impression emerged that the ideomotor principle could be conceptualized in terms of a two-channel hypothesis for processing visual and auditory information. This model represented an appreciable elaboration on the old ideomotor principle and served a useful heuristic guide at this stage of research. Another analogous, useful way of conceptualizing the distinction between processing visual and auditory information found in the pendulum effect is that two disparate symbolization systems exist. The distinction between the two systems seems fundamentally to center around the concreteness-abstractness of the symbols processed. Moving visual signals suggestive of movement, visual kinetic images, and actual ideomotor movement are all in the same concrete realm in the sense that they all have a direct spatial character and occur in a three-dimensional space which is directly perceived or represented internally. Verbal-auditory signals and images, however, are in a different realm in that they are in a different sensory modality, are not as often used to represent a three-dimensional space, are often more symbolic, and thus more abstract. Visual schematic symbolizations are indeed abstractions from sensations and perception but the verbal-auditory system represents higher-order abstractions likely facilitated developmentally by the emergence of language.

This distinction actually seemed implicit in the nineteenth century formulations of ideomotor behavior--that is, a more concrete idea could be realized in concrete motoric expression more readily than an abstract idea--but it was never empirically verified. Those observations leading to conceiving of the effect as worthy of study in its own right tended to be ignored. The present pendulum method was used to explore specifically ideomotor action.

Perhaps the major conclusion which can be drawn from these experiments is that the traditional notion of "suggestibility" involves two major components. First, suggestibility without doubt involves factors of conscious or unconscious compliance based on beliefs, expectations, influence commands, exhortation, etc. This component represents a traditional interpretation and has been the focus of extensive study over the past century. What have been generally ignored, however, are the specific parameters of those ideomotor phenomena used to demonstrate suggestive effects that often prove to be sensitive to social, interpersonal manipulations. The present studies provide substantial evidence that a second component of "suggestibility" is a perceptual/ cognitive skill which can be explored apart from compliance to direct or indirect influence communications.

VII. BIBLIOGRAPHY

Annet, J. Feedback and human behavior. Baltimore: Penguin Books, 1969.

Arnold, M. B. On the mechanism of suggestion and hypothesis. Journal of Abnormal and Social Psychology, 1946, 41, 107-128.

Aronfreed, J. The problem of imitation. In L. Lipsitt & H. Reese (Eds.), Advances in child development and behavior. Vol. 4. New York: Academic Press, 1969.

Attneave, F. Representation of physical space. In A. Melton & E. Martin (Eds.), Coding processes in human memory. Washington, D. C.: Winston, 1972.

Atwood, G. E. An experimental study of visual imagination and memory. Cognitive Psychology, 1971, 2, 290-299.

Bandura, A. Psychological modeling: Conflicting theories. Chicago: Aldine-Atherton, 1971.

Benton, A. L., & Bandura, A. 'Primary and Secondary' suggestibility. Journal of Abnormal and Social Psychology, 1953, 48, 336-340.

Bower, G. H. Mental imagery and associative learning. In L. Gregg (Ed.), Cognition in learning and memory. New York, Wiley, 1972.

Brooks, L. Visual and verbal processes in internal representation. Paper presented at a colloquium series sponsored by the Salk Institute, La Jolla, California, July, 1970. This series to be published as a volume edited by Eugene Galanter.

Carpenter, W. B. Principles of mental physiology, with their applications to the training and discipline of the mind and study of its morbid conditions. New York: Appleton, 1884.

Chevreul, M. E. Lettre à M. Ampère sur une classe particulaires. Review des deux mondes, 1833, 2(2nd ser.), 258-266.

Chevreul, M. E. De la bequette divinatoire, du pendulue explorateur, des tables tournates, au point de vue de l'histoire, de la critique et de la méthode éxpérimentale. Paris: Mallet-Bachelier, 1854.

Church, J. Language and the discovery of reality. New York: Vintage Books, 1961.

Crandall, S. H., & Marks, W. D. Random vibration in mechanical systems. New York: Academic Press, 1963.

Easton, R. D. An experimental analysis of the Chevreul pendulum illusion. Unpublished master's thesis, University of New Hampshire, 1972.

Ellenberger, H. F. The discovery of the unconscious: The history and evolution of dynamic psychiatry. New York: Basic Books, 1970.

Estabrooks, G. H. Experimental studies in suggestion. Journal of Genetic Psychology, 1926, 36, 120-139.

Evans, F. J. Suggestibility in the normal waking state. Psychological Bulletin, 1967, 67, 114-129.

Eysenck, H. J., & Furneaux, W. D. Primary and secondary suggestibility: An experimental and statistical study. Journal of Experimental Psychology, 1945, 35, 485-503.

Eysenck, H. J. Dimensions of personality. London: Routledge & Kegan Paul, 1947.

Gibson, J. J. The senses considered as perceptual systems. Boston: Houghton-Mifflin, 1966.

Heid, R. Plasticity in sensory-motor systems. Scientific American, 1965, 213, 84-94.

Hull, C. L. Hypnotism and suggestibility. New York: Appleton-Century, 1933.

Jacobson, E. The electrophysiology of mental states. American Journal of Psychology, 1932, 44, 677-694.

James, W. The principles of psychology. New York: Holt, 1890. 2 vols. (Reprinted by Dover Publications, 1950).

Jastrow, J. Error and eccentricity in human belief. New York: Dover, 1962. (Formerly titled: Wish and wisdom: Episodes in the vagaries of belief. New York: Appleton-Century, 1935.)

Lincoln, R. S. Learning a rate of movement. Journal of Experimental Psychology, 1954, 47, 465-470.

Lincoln, R. S. Learning and retaining a rate of movement with the aid of verbal and kinesthetic cues. *Journal of Experimental Psychology*, 1956, *51*, 199-204.

McGuigan, F. J. *Thinking: Studies of covert language processes*. New York: Appleton, 1966.

McGuigan, F. J. Covert oral behavior during the silent performance of language tasks. *Psychological Bulletin*, 1970, *74*, 309-326.

MacKay, D. M. Mindlike behaviour in artifacts. *British Journal for the Philosophy of Science*, 1951, *2*, 105-121.

Max, L. W. An experimental study of the motor theory of consciousness. III. Action-current responses in deaf mutes during sleep, sensory stimulation, and dreams. *Journal of Comparative Psychology*, 1935, *19*, 469-486.

Max, L. W. An experimental study of the motor theory of consciousness. IV. Action-current responses in the deaf during awakening, kineasthetic imagery, and abstract thinking. *Journal of Comparative Psychology*, 1937, *24*, 301-344.

Mayo, H. *On the truths contained in popular superstitions with an account of mesmerism*. (3rd ed.) London: Blackwood, 1851.

Miller, G. A., & Galanter, E., & Pribram, K. H. *Plans and the structure of behavior*. New York: Holt, Rinehart, & Winston, 1960.

Neisser, U. Changing conceptions of imagery. In P. Sheehan (Ed.), *The function and nature of imagery*. New York: Academic Press, 1972.

Orne, M. T. The nature of hypnosis: Artifact and essence. *Journal of Abnormal and Social Psychology*, 1959, *46*, 213-225.

Orne, M. T. On the social psychology of the psychological experiment: With particular reference to demand characteristics and their implications. *American Psychologist*, 1962, *17*, 776-783.

Orne, M. T. Demand characteristics and the concept of quasi-controls. In R. Rosenthal & R. Rosnow (Eds.), *Artifact in behavioral research*. New York: Academic Press, 1969.

Paivio, A. Imagery and verbal processes. New York: Holt, Rinehart, & Winston, 1971.

Piaget, J. Play, dreams, and imitation in childhood. New York: Norton, 1951.

Piaget, J., & Inhelder, B. Mental imagery in the child. New York: Basic Books, 1971.

Pylyshyn, Z. W. What the mind's eye tells the mind's brain: A critique of mental imagery. Psychological Bulletin, 1973, 80, 1-24.

Richardson, A. Mental imagery. New York: Springer, 1969.

Segal, S. J., & Fusella, V. Influence of imaged pictures and sounds on detection of visual and auditory signals. Journal of Experimental Psychology, 1970, 83, 458-464.

Segal, S. J., & Fusella, V. Effect of images in six sense modalities on detection of visual signal from noise. Psychonomic Science, 1971, 24(2), 55-56.

Sheehan, P. W. A shortened form of Betts Questionnaire upon Mental Imagery. Journal of Clinical Psychology, 1967, 23, 386-389.

Sheehan, P. W. The function and nature of imagery. New York: Academic Press, 1972.

Shor, R. E. The three-factor theory of hypnosis as applied to the book-reading fantasy and to the concept of suggestion. International Journal of Clinical and Experimental Hypnosis, 1970, 18, 89-98.

Shor, R. E. The fundamental problem in hypnosis research as viewed from historic perspectives. In E. Fromm & R. E. Shor (Eds.), Hypnosis: Research developments and perspectives. Chicago: Aldine, 1972.

Smith, K. Curare drugs and total paralysis. Psychological Review, 1964, 71, 77-79.

Smith, K. Behavior and conscious experience: A conceptual analysis. Ohio: Ohio University Press, 1969.

Smith, K. U. Delayed sensory feedback and behavior. Philadelphia: Sauders, 1962.

Smith, S. M., Brown, H. O., Teman, J. E. P., & Goodman, L. S. The lack of cerebral effects of d-tubocurarine. Anesthesiology, 1947, 8, 1-14.

Thorndike, E. L. Ideo-motor action. Psychological Review, 1913, 20, 91-106.

Watson, J. B. Behaviourism. (2nd ed.) New York: Norton, 1930.

TABLE 1

MEAN DIFFERENCES OF THREE INSTRUCTION GROUPS IN EXPERIMENT I

	Concentrate on pendulum not moving	Concentrate on pendulum moving	Remain Neutral
Angle (degrees) subtended by pendulum swing	0.32	11.03	0.94

TABLE 2

FIVE FACTOR MIXED ANALYSIS OF VARIANCE DESIGN

Independent groups factors	Factor A (p = 3)--Instructions	
		a_1 = Concentrate on the pendulum moving and the hand remaining still
		a_2 = Concentrate solely on the pendulum moving
		a_3 = Concentrate on the pendulum moving and count backwards by threes
	Factor E (t = 2)--Sex	
		e_1 = Males
		e_2 = Females
Repeated measures factors	Factor B (q = 2)--Musculature Inovlved in Suspension	
		b_1 = Arm supported at the wrist
		b_2 = Body free-standing
	Factor C (r = 2)--Visual Prompts	
		c_1 = Without visual prompts
		c_2 = With visual prompts
	Factor D (s = 2)--Auditory Prompts	
		d_1 = Without auditory prompts
		d_2 = With auditory prompts

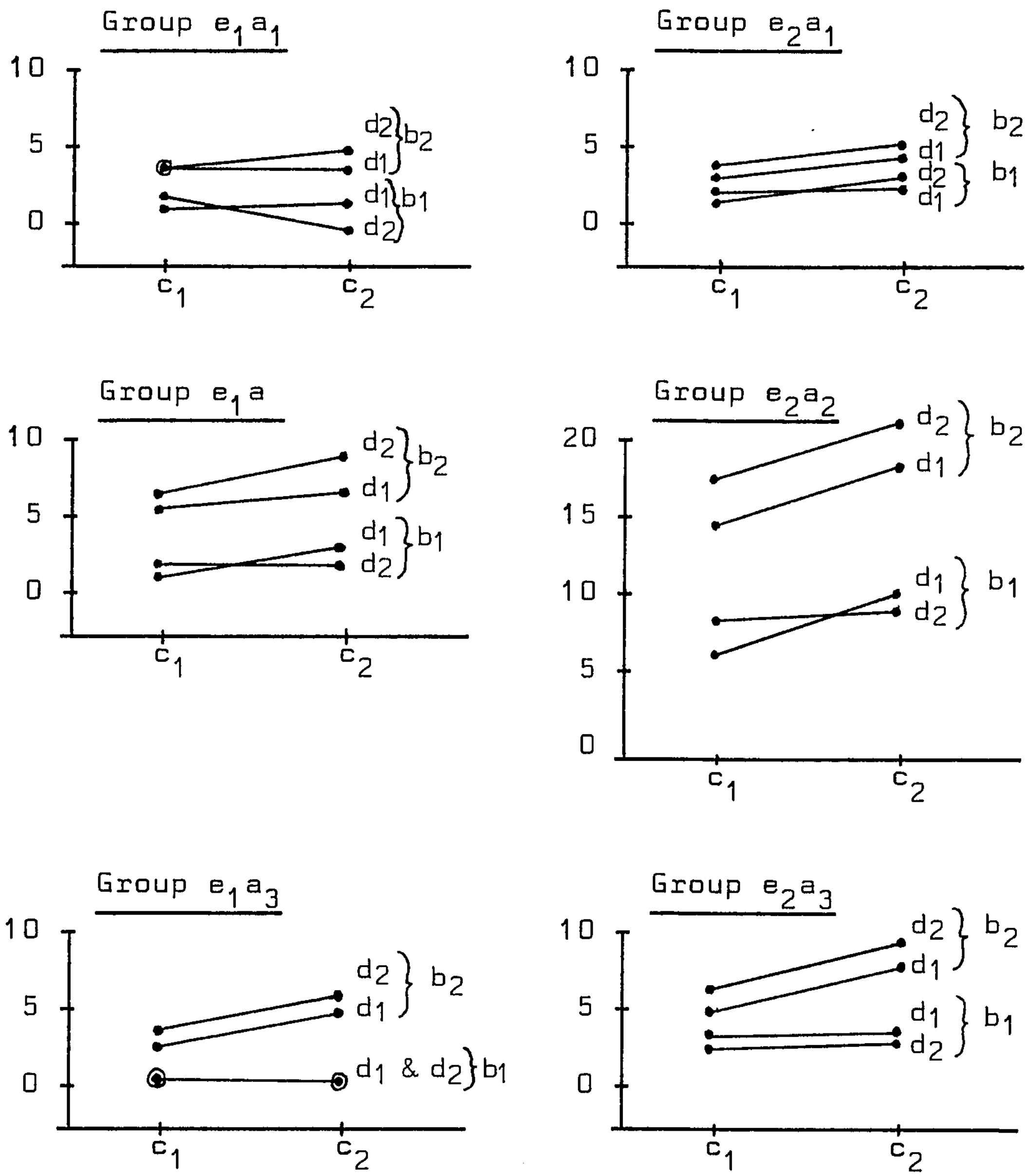

Fig. 1. Graphic display of the means in experiment II. The dependent measure is degrees of arc of pendulum swing.

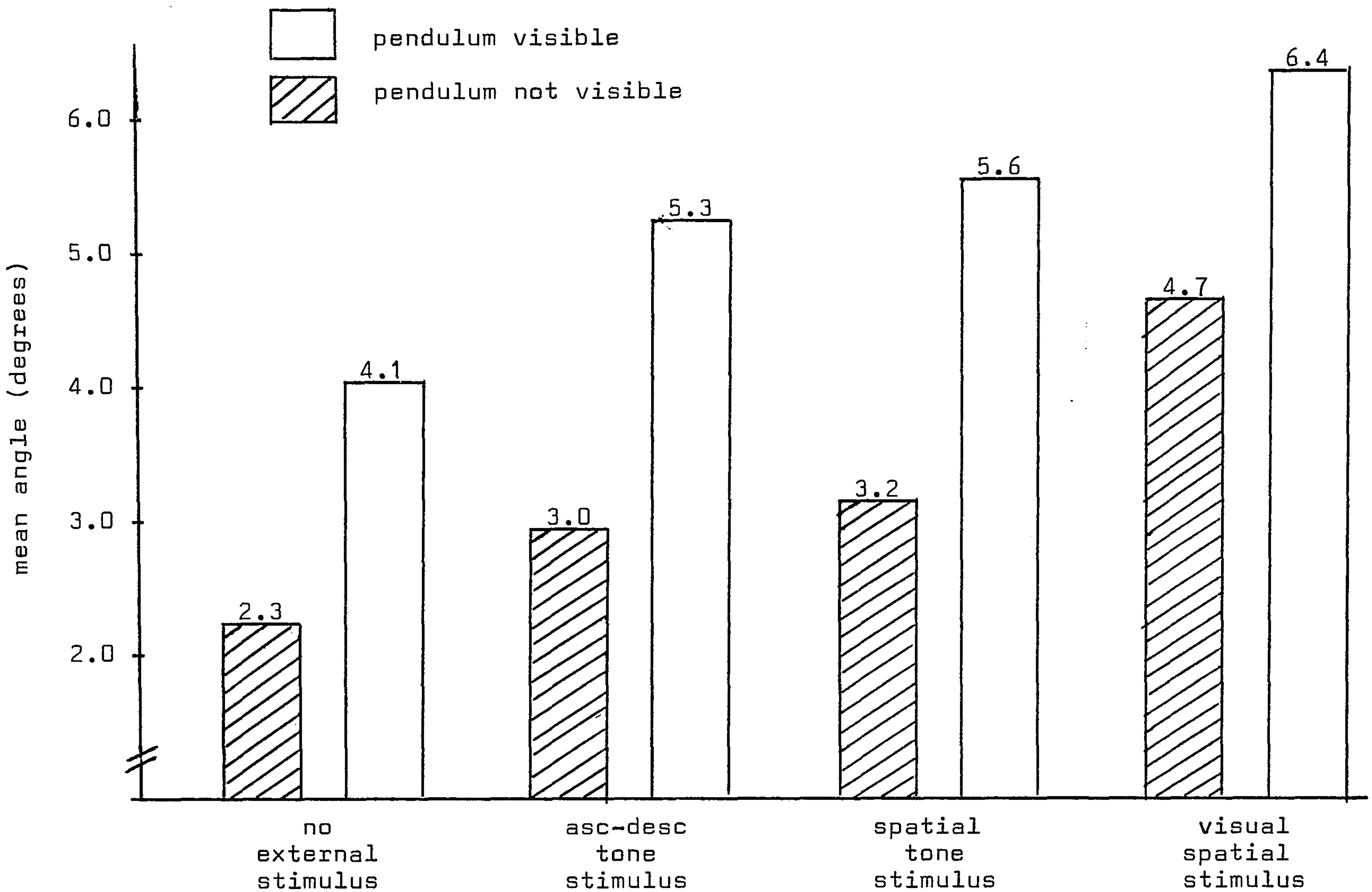

Fig. 2. The effect of imaginal prompts vs. visual feedback of pendulum oscillations in experiment III.

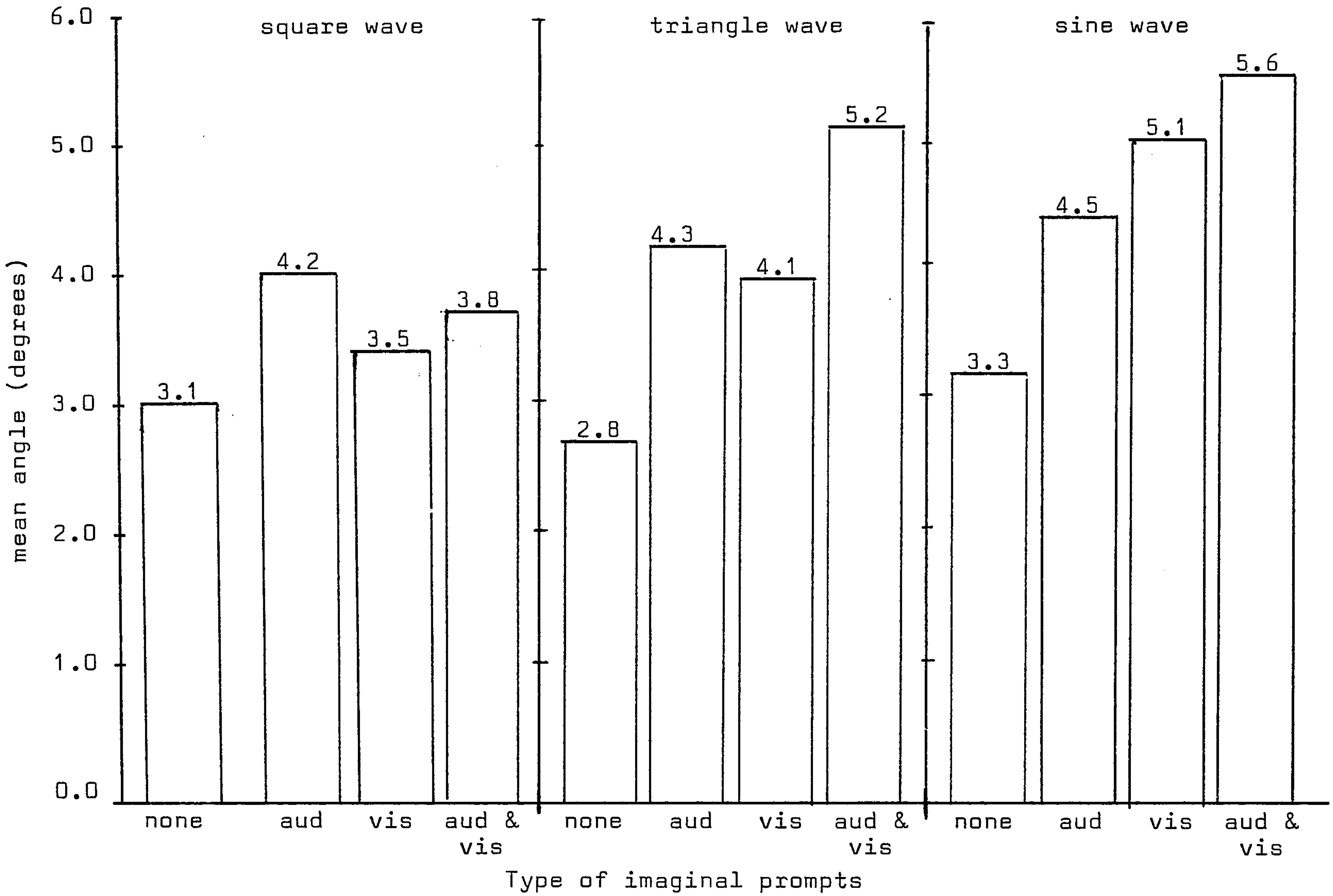

Fig. 3. Mean differences for imaginal prompts generated with different wave forms in experiment IV.

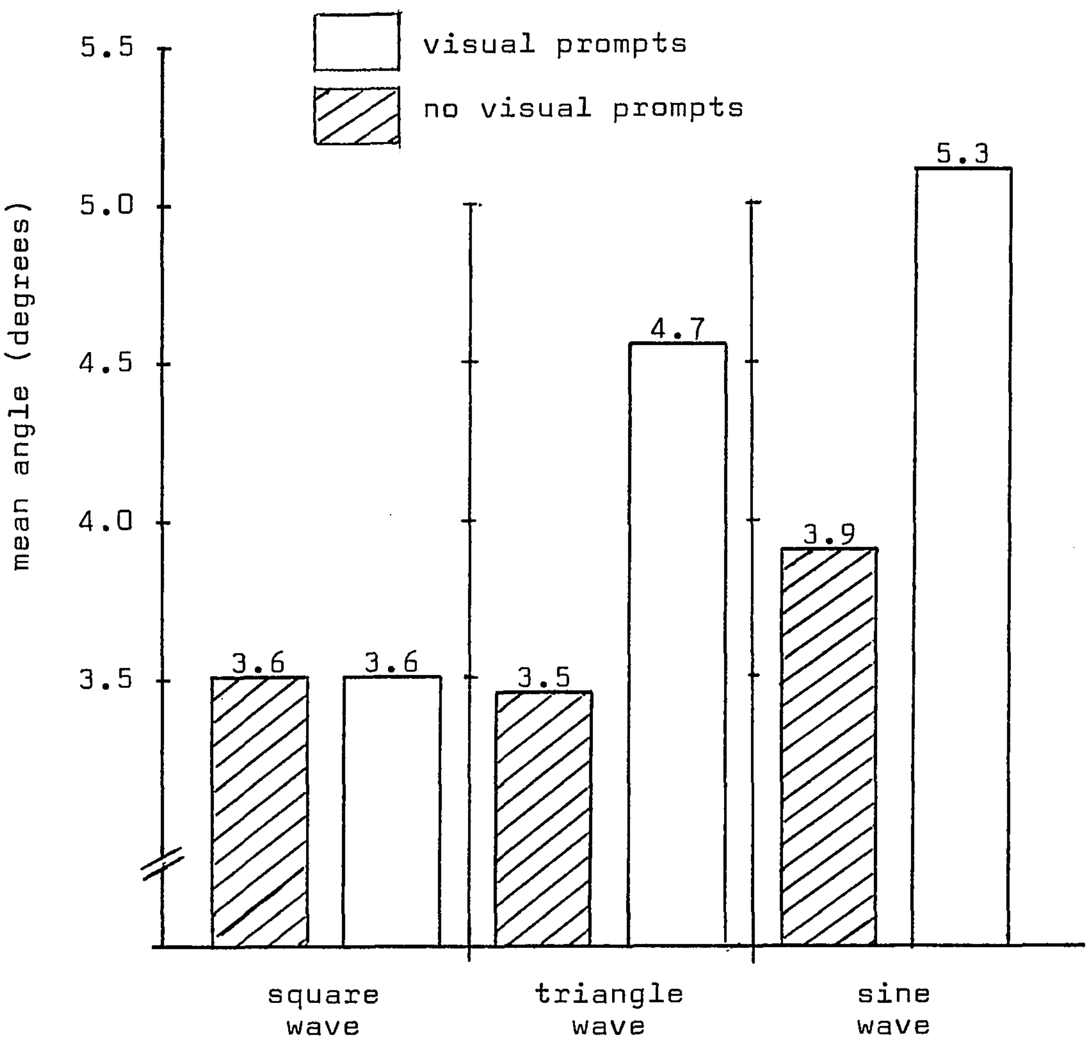

Fig. 4. Visual prompts-X-wave
from interaction in experiment IV.

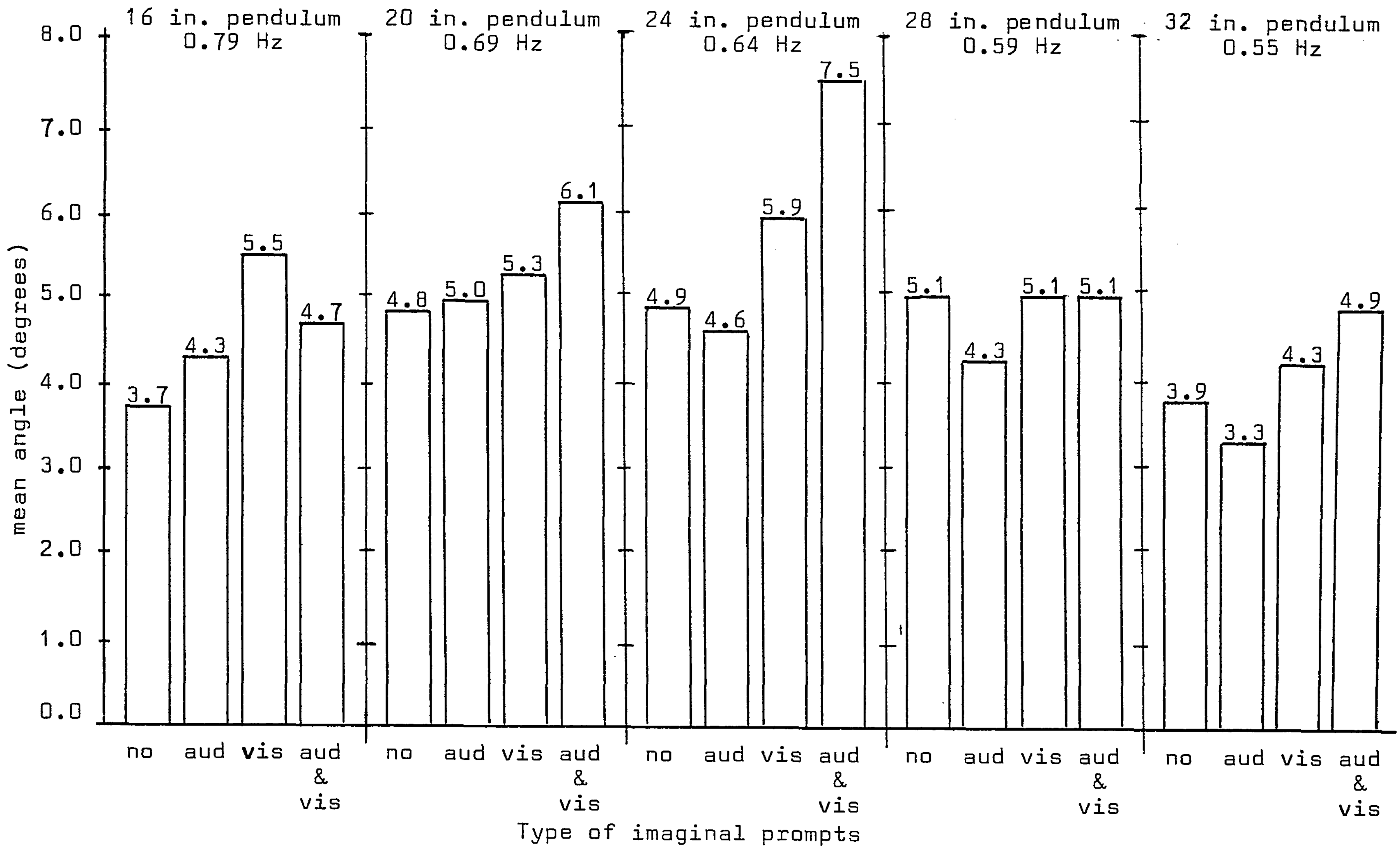

Fig. 5. The effect of different length pendulums with fixed frequency imaginal prompts in experiment V.

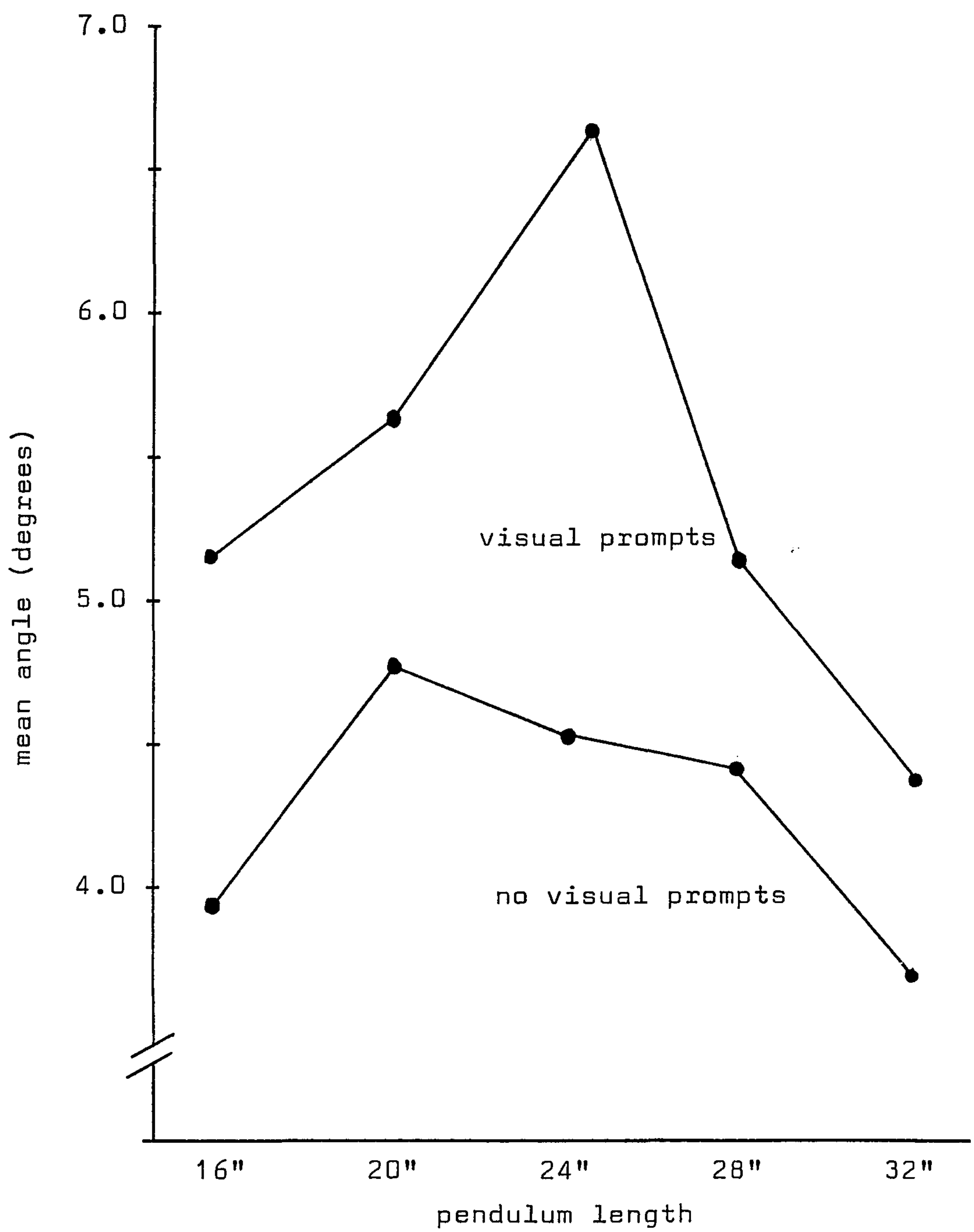

Fig. 6. Visual prompts-X-pendulum length interaction in experiment V.

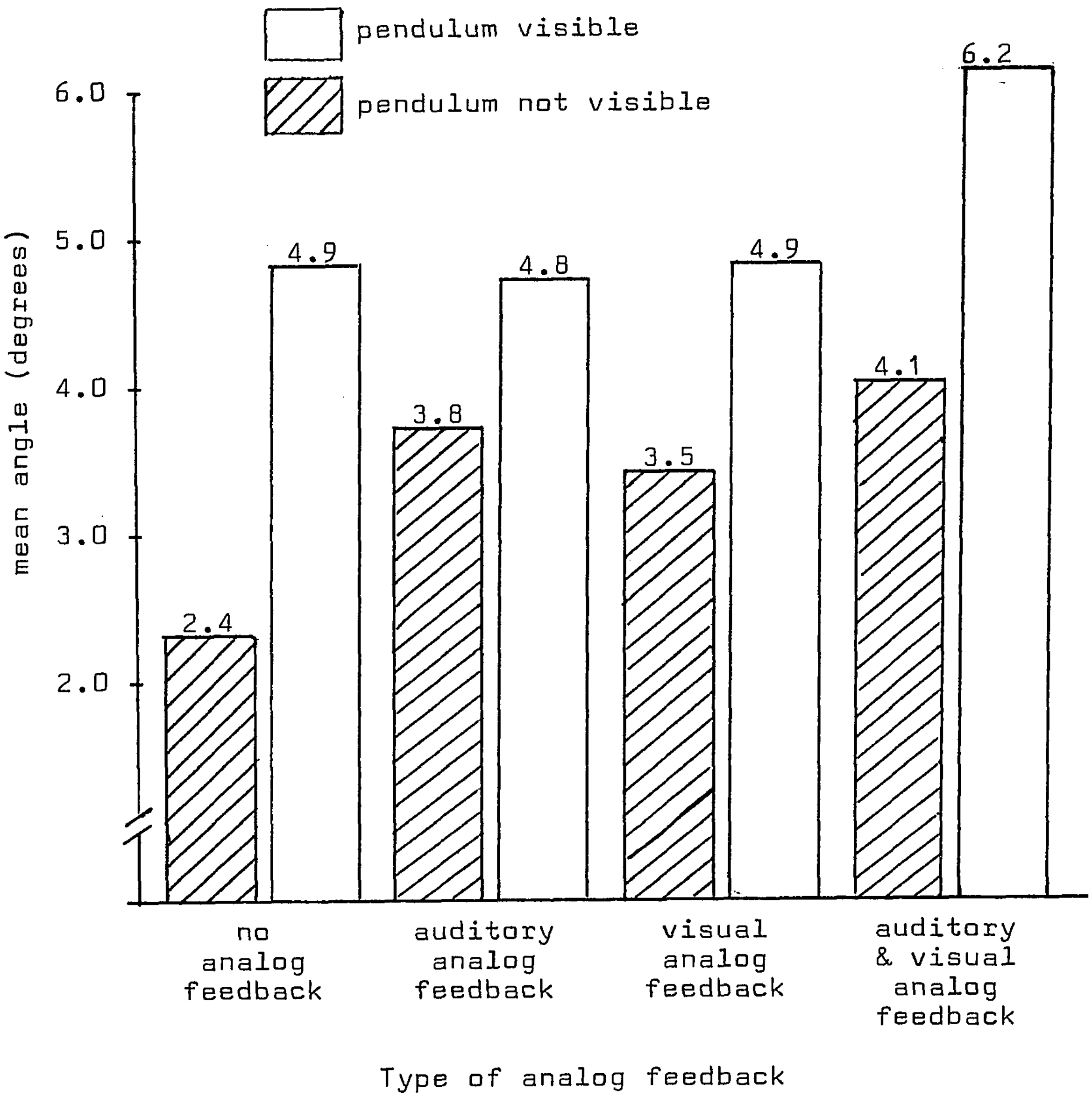

Fig. 7. The effect of analog reafferent feedback on the ideomotor process in experiment VI.

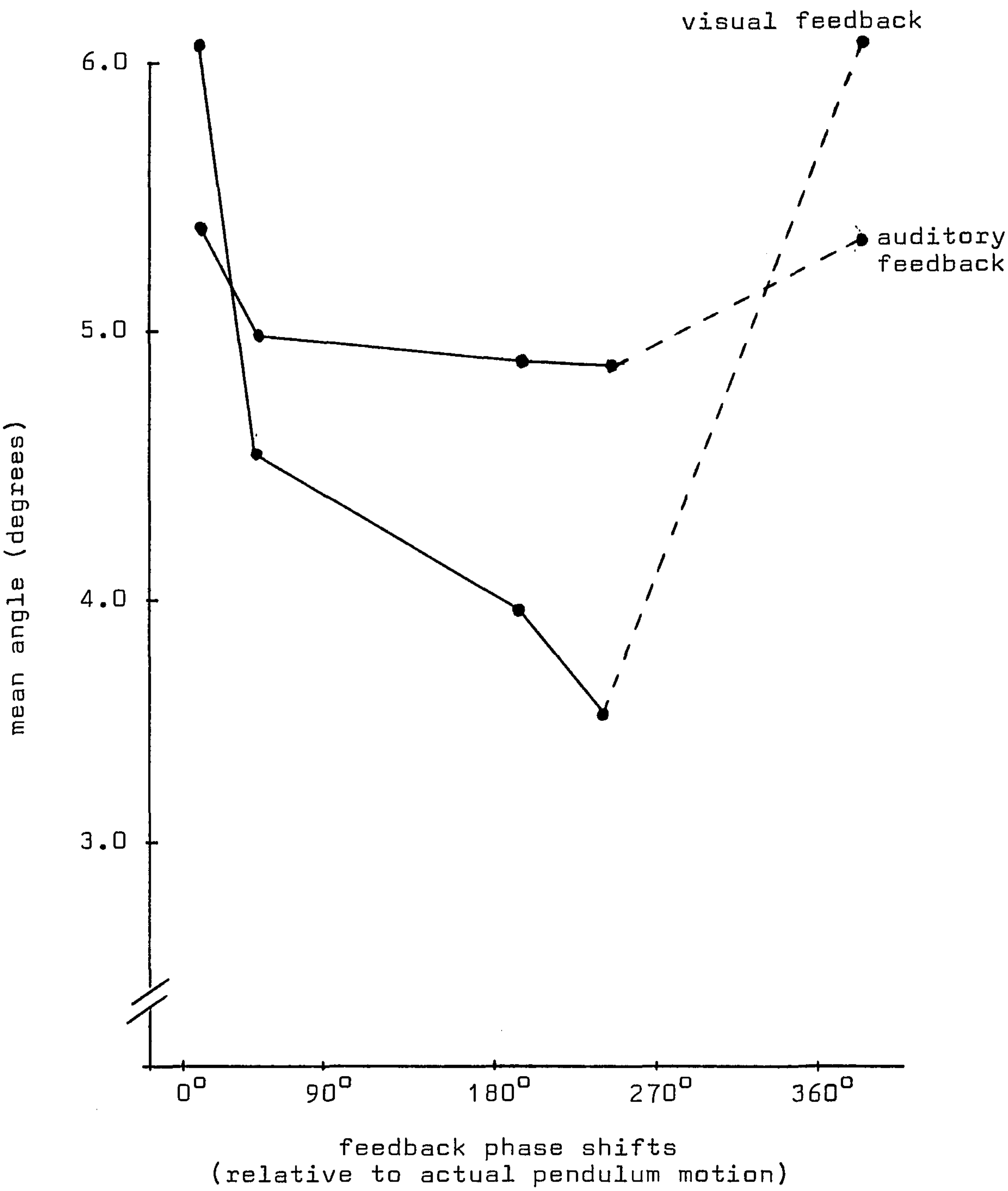

Fig. 8. Feedback modality-X-feedback phase shifts interaction in experiment VII. (Dotted lines are hypothetical trends, not experimentally derived data.)

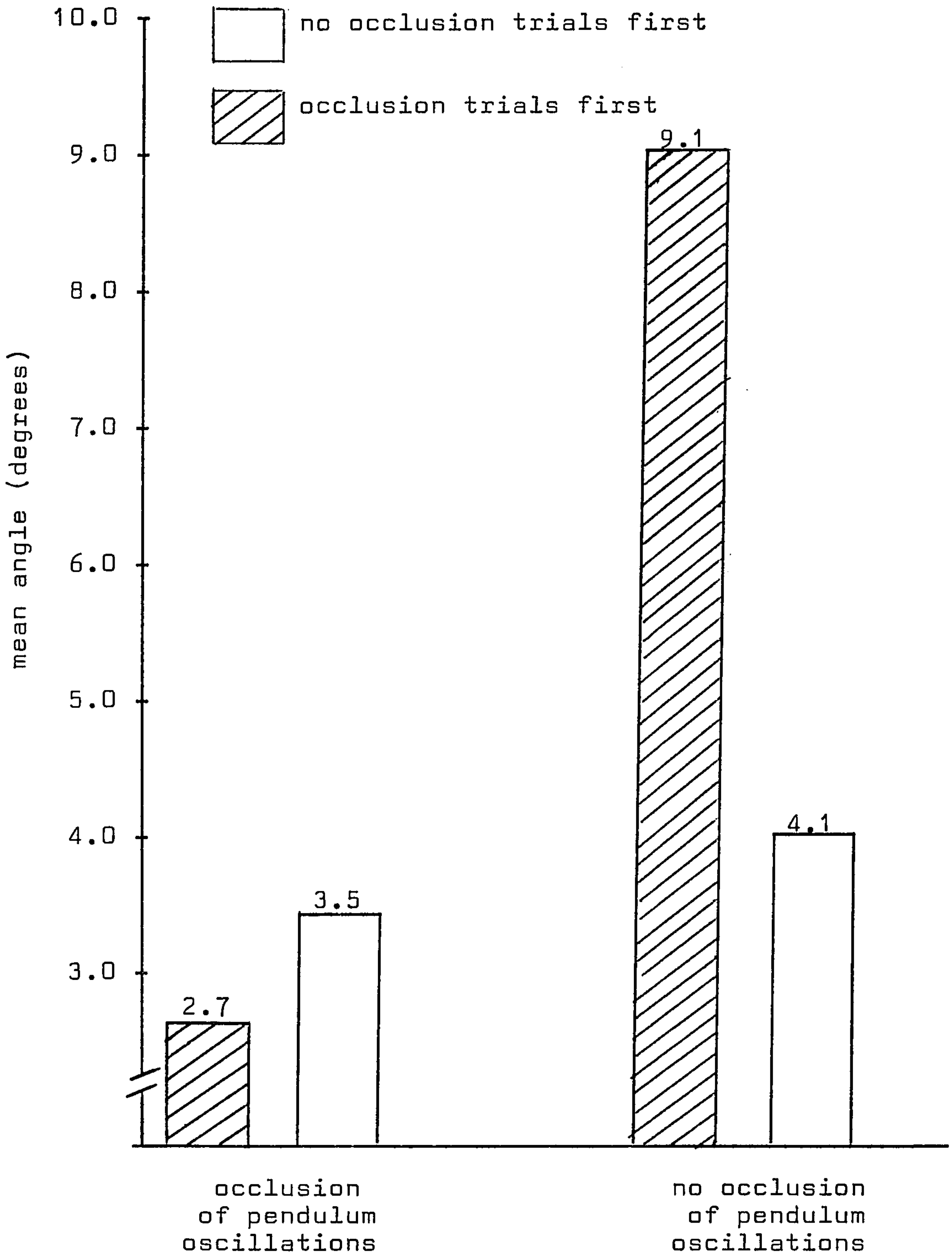

Fig. 9. Occlusion of pendulum oscillations-X-order of occlusion trials interaction in experiment VII.

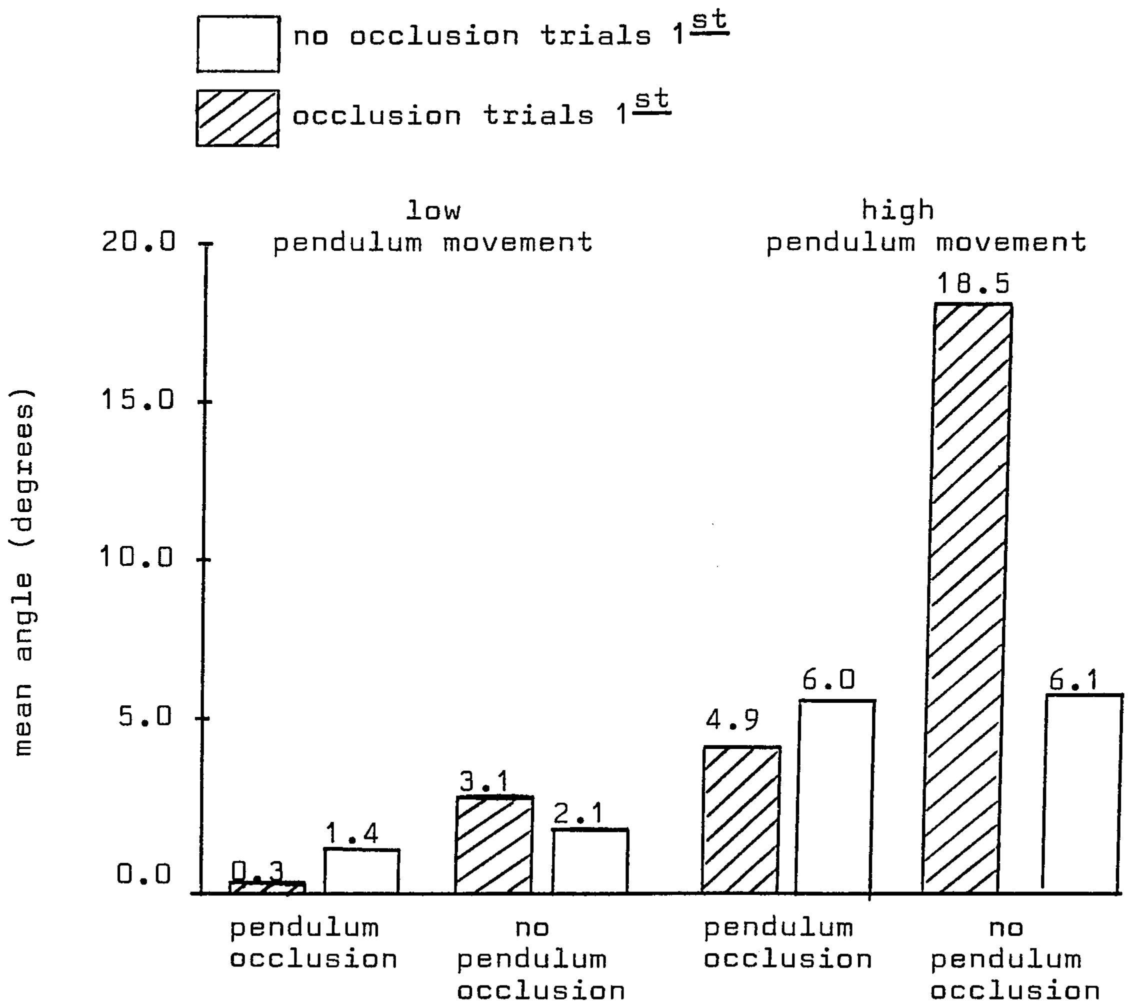

Fig. 10. Occlusion of pendulum oscillations-X-order of occlusion trials interaction for low and high pendulum movement in experiment VII.

APPENDIX

ANOVA SUMMARIES

Experiment I

ANOVA Summary

Source	*df*	*SS*	*MS*	*F*	*p*
Within *S*'s	20	1,164.98			
A - instructions	2	722.99	361.49	14.72	.001
S's w/group	18	441.99	24.55		
Total	20	1,164.98			

Experiment II

ANOVA Summary

Source	df	SS	MS	F	p
Between S's	59	29,852.05			
A - instructions	2	3,724.57	1,862.28	4.60	.05
E - sex	1	2,396.24	2,396.24	5.92	.05
AE	2	1,862.03	931.02	2.30	
S's w/group	54	21,869.21	404.99		
Within S's	420	7,013.04			
B - musculature	1	2,113.73	2,113.73	42.60	.001
AB	2	530.02	265.01	5.34	.050
EB	1	58.86	58.86	1.19	
AEB	2	261.28	130.64	2.63	
B x S's w/group	54	2,679.08	49.61		
C - visual prompts	1	228.94	228.94	32.57	.001
AC	2	29.78	14.89	2.12	
EC	1	13.98	13.98	1.99	
AEC	2	2.68	.34	.19	
C x S's w/group	54	379.82	7.03		
D - auditory prompts	1	21.55	21.55	14.65	.001
AD	2	9.80	4.90	3.33	.050
ED	1	5.88	5.88	4.00	
AED	2	5.05	2.52	1.70	
D x S's w/group	54	79.23	1.47		
BC	1	48.28	48.28	15.33	.001
ABC	2	9.11	4.55	1.44	
EBC	1	1.16	1.16	.37	
AEBC	2	1.34	.67	.21	
BC x S's w/group	54	169.91	3.15		

BC	1	20.07	20.07	12.20	.001
ABD	2	7.54	3.77	2.30	
EBD	1	7.03	7.03	4.29	.050
AEBD	2	2.67	1.33	.81	
BD x S's w/group	54	88.73	1.64		
CD	1	1.32	1.32	.52	
ACD	2	2.16	1.08	.42	
ECD	1	.03	.03	.01	
AECD	2	4.14	2.07	.81	
CD x S's w/group	54	137.54	2.55		
BCD	1	.29	.29	.19	
ABCD	2	7.03	3.52	2.33	
EBCD	1	.04	.04	.03	
AEBCD	2	3.43	1.72	1.14	
BCD x S's w/group	54	81.54	1.51		
Total	479	36,865.09			

Experiment III

ANOVA Summary

Source	*df*	*SS*	*MS*	*F*	*p*
Within *S*'s	105	584.34			
A - occlusion	1	122.81	122.81	6.33	.05
A x *S*'s w/group	14	271.55	19.39		
B - type of prompts	3	84.88	28.29	18.80	.001
B x *S*'s w/group	42	63.20	1.50		
AB	3	2.23	.74	.79	
AB x *S*'s w/group	42	39.67	.94		
Total	105	584.34			

Experiment IV

ANOVA Summary

Source	df	SS	MS	F	p
Within S's	132	293.90			
A - wave forms	2	23.02	11.51	9.80	.001
A x S's w/group	22	25.83	1.17		
B - visual prompts	1	28.89	28.89	10.16	.010
B x S's w/group	11	31.27	2.84		
C - auditory prompts	1	29.97	29.97	11.83	.010
C x S's w/group	11	27.86	2.53		
AB	2	14.33	7.16	11.95	.001
AB x S's w/group	22	13.19	.59		
AC	2	2.12	1.06	.89	
AC x S's w/group	22	27.47	1.24		
BC	1	3.45	3.45	.87	
BC x S's w/group	11	43.58	3.96		
ABC	2	.25	.13	.12	
ABC x S's w/group	22	22.67	1.03		
Total	132	293.90			

Experiment V

ANOVA Summary

Source	df	SS	MS	F	p
Within S's	380	1,925.86			
A - length of pendulum	4	126.79	31.69	5.56	.001
A x S's w/group	76	433.19	5.69		
B - visual prompts	1	108.57	108.57	19.51	.001
B x S's w/group	19	105.75	5.57		
C - auditory prompts	1	1.23	1.23	.48	
C x S's w/group	19	48.67	2.56		
AB	4	26.92	6.73	2.59	.050
AB x S's w/group	76	197.28	2.59		
AC	4	15.54	3.88	1.12	
AC x S's w/group	76	266.12	3.50		
BC	1	9.79	9.79	.79	
BC x S's w/group	19	233.63	12.29		
ABC	4	30.73	7.68	1.81	
ABC x S's w/group	76	321.65	4.23		
Total	380	1,925.86			

Experiment VI

ANOVA Summary

Source	df	SS	MS	F	p
Within S's	98	320.42			
A - occlusion	1	77.55	77.55	19.05	.001
A x S's w/group	13	52.90	4.07		
B - visual feedback	1	11.70	11.70	5.76	.050
B x S's w/group	13	26.40	2.03		
C - auditory feedback	1	16.66	16.66	5.48	.050
C x S's w/group	13	39.47	3.03		
AB	1	.10	.10	.06	
AB x S's w/group	13	23.05	1.77		
AC	1	1.75	1.75	.85	
AC x S's w/group	13	26.55	2.04		
BC	1	.13	.13	.15	
BC x S's w/group	13	10.94	.84		
ABC	1	8.57	8.57	4.52	.100
ABC x S's w/group	13	24.65	1.89		
Total	98	320.42			

Experiment VII

ANOVA Summary

Source	df	SS	MS	F	p
Between S's	29	8,420.65			
A - order of occlusion trials	1	510.67	510.67	1.81	
S's w/group	28	7,909.98	282.49		
Within S's	450	9,847.95			
B - occlusion	1	1,456.36	1,456.36	10.80	.01
AB	1	1,023.45	1,023.45	7.59	.05
B x S's w/group	28	3,774.61	134.81		
C - feedback modality	1	21.89	21.89	1.01	
AC	1	12.51	12.51	.57	
C x S's w/group	28	608.62	21.73		
D - phase shifts	3	144.65	48.21	5.13	.01
AD	3	26.73	8.91	.95	
D x S's w/group	84	788.05	9.38		
BC	1	.69	.69	.10	
ABC	1	.63	.63	.09	
BC x S's w/group	28	186.25	6.65		
BD	3	33.49	11.16	1.57	
ABD	3	2.02	.67	.09	
BD x S's w/group	84	595.59	7.09		
CD	3	74.70	24.90	3.49	.05
ACD	3	13.63	4.54	.63	
CD x S's w/group	84	599.64	7.13		
BCD	3	16.85	5.61	1.01	
ABCD	3	1.06	.35	.06	
BCD x S's w/ group	84	466.53	5.55		
Total	479	18,268.60			