PERCEPTUAL COMPONENTS IN CONSERVATION OF HORIZONTALITY TASKS.

by

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ABSTRACT

Recent studies (e.g., Morris, 1971; Thomas et. al., 1973) have shown that many high school and college age subjects, especially women, do not predict correctly that the water level in a partially filled container remains horizontal regardless of the tilt of that container. Although Thomas has suggested that the poorer performance by women on such conservation of horizontality tasks is due to a conceptual deficit, an alternative explanation (Perper and Chase, 1974; Harris, 1975) is that these tasks involve visuo-spatial skills in which males have traditionally excelled. The purpose of our research was to investigate whether field effects such as those involved in field dependence-independence affect performance on conservation of horizontality tasks.

Forty-eight senior high school students (Experiment 1a) and 158 introductory psychology students (Experiment 1b) were required to draw a water line to indicate how the water level would look in a series of drawings representing bottles at various degrees of tilt. Subjects in the Cue condition received drawings of bottles with false water lines which misrepresented what the water level should actually look like. Subjects in the No Cue condition received drawings with no water levels drawn in. Women, being more field dependent than men, were expected

to be more misled by the conflicting cues. This hypothesis was substantiated, with women performing as well as men when misleading cues were absent, but more poorly than the men when there were false cues present.

Since the paper and pencil study suggested that field effects were affecting performance, it was decided to look directly at what role these might play in a typical conservation of horizontality paradigm, but one where subjects are specifically instructed to set the water line to the horizontal. A Thomas (1975) type of apparatus was used. It consisted of an empty bottle mounted in front of a half-red half-white rotatable disc. Sixty-four introductory psychology students (Experiment 2) were given a series of bottle orientations for which they were specifically instructed to set the line (red-white boundary) to the horizontal position. After this half of the subjects were given a series of trials with a rod and frame apparatus. As expected, oblique bottle orientations were found to be more difficult than those which were vertical or horizontal, especially by women. The most important finding was that, as hypothesized, performance on the oblique bottle orientations was highly correlated with performance on the rod and frame test.

These studies argue against Thomas's (1973) contention that the sex difference in performance on conservation of horizontality is solely due to a conceptual deficit in women. The data presented here support the suggestions of researchers such as Perper and Chase (1974) and Harris (1975) that tasks generally used to study conservation of horizontality involve perceptual components related to visuo-spatial skills such as those involved in field dependence-independence.

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INTRODUCTION

Piaget and Inhelder (1956) have shown that children's perception and understanding of spatial relations is strikingly deficient in the utilization of an external frame of reference based upon a Cartesian coordinate system with Euclidian properties. In the classical test for conservation or representation of horizontality, the child is shown a partially filled bottle of water. He is then asked to predict the position of the water when the bottle is tilted to various orientations. Piaget and Inhelder hypothesize that the inability of young children to recognize the principle that still water remains invariantly horizontal regardless of the tilt of the container is based upon an "inability to evaluate the perceptual data in terms of the orientation of lines and planes"(p.390). The acquisition of effective conceptualization of the entire spatial environment in terms of a Euclidean coordinate system proceeds in a series of stages culminating at formal operations. A child of four or five years of age does not as yet abstract lines and planes from his spatial field. Two or three years later he begins to define spatial relations in terms of Euclidean relationships but still fails to predict horizontality in a tilted container because of a failure to utilize a frame of reference external to the container. Although many children at this stage seem to recognize that the water line stays constant, they see it as constant not in relation to an external frame of reference but in relation to the container. Thus a typical response at this stage is to show the water as being parallel to the bottom of the container. Only when the child begins to analyze the perceptual data in terms of an external frame of reference is conservation of horizontality possible.

Although Piaget and Inhelder's theory suggests that the spatial concepts required for horizontality should be firmly established by late childhood, recent research literature suggests that many college age subjects seem to have difficulty with the conservation of horizontality. In one of the first studies showing this puzzling result, Rebelsky (1964) presented pictures of partially filled glasses of water to graduate and undergraduate psychology students. Subjects were required to indicate how the surface of the water would look if the bottles were tilted 30 and 60 degrees from the vertical. The results showed that a surprisingly high number of students (65%) made errors of more than five degrees. In addition, although the degree of tilt was not found to be significant in the overall sample, females made significantly more errors than males on the 60 degree bottle tilts. Although this possible sex difference was not discussed by Rebelsky, differences between the performance of men and women became one of the primary areas of focus in future research on conservation of horizontality.

Rebelsky's contention that adults seem to have difficulty, much as children do, with the concept of horizontality was challenged in a later study carried out by Barna and O'Connell (1967). Using a similar procedure to that of Rebelsky they studied subjects of three different age groups: seven to eight years, nine to ten years, and college freshman. Barna and O'Connell reported, in contrast to Rebelsky, that the responses of college age subjects were not at all similar to the responses made by young children. Their conclusion was that whereas both groups of children did not seem to grasp the concept of horizontality, the college freshmen did use this concept adequately. Yet if one looks at the raw data means reported by Barna and O'Connell, the firmness of their conclusion is questionable. The average error of the college sample on bottles tilted at 60 degrees was 10.1 degrees. Although this is significantly less than that of the children (Error mean=56.8 degrees), it is still a substantial error, one that would not be expected if subjects understood the principle of horizontality. In addition, college age subjects as well as children found the 60 degree bottle orientation significantly more difficult than the 30 degree orientation. In light of Rebelsky's finding that women have a greater difficulty than men with the 60 degree bottle tilt, it is regrettable that Barna and O'Connell gave no information about possible sex differences.

The next study exploring horizontality in college age subjects was carried out by Morris (1971). Theoretically this was an important study because for the first time it was hypothesized that a sex difference would be found and a possible explanation was offered. Morris theorized that women perform more poorly in conservation of horizontality with oblique bottle orientations because they are more field dependent than men. As a result of this he hypothesized that if an additional cue condition was employed (a horizontal line drawn a few inches below the tilted containers), women would rely more heavily upon this cue and with this aid improve their performance. This would show up in the data analysis as a sex by cue interaction with the performance of women but not men changing as a function of presence versus non-presence of the additional cue.

Results showed that as expected women made greater errors than men. Also, as suggested by the data of Barna and O'Connell, subjects found 60 degree orientations more difficult than the 30 degree tilts. The sex by cue interaction never materialized and Morris concluded that the "field dependency hypothesis was not substantiated" (p.827). But the results are not really that unexpected even if we do assume that field dependence is the primary controlling variable behind the sex difference present. The experiment was carried out in a well lit environment with numerous salient horizontal cues such as tables and floor. If a subject was not effectively utilizing these natural environmental cues in determining the horizontal, it is doubtful that a drawn cue below the tilted containers would be more effective in producing a correct response.

The research that served to generate a great deal of experimental and theoretical interest in the area of conservation of horizontality was reported in a series of comprehensive articles by H. Thomas (1973,1974,1975). Thomas developed an ingenious apparatus to study horizontality. It consisted of two rotatable bottles. One was half full of water and was called the 'model,' while the other called the 'pretend bottle' was empty but contained an adjustable 'mock' water line. In the actual testing sessions both bottles were positioned to the same orientation and subjects were required to predict the position of the water in the model (which was covered) by adjusting the mock water line in the pretend bottle.

In a series of developmental studies with subjects ranging from nursery school through to college age, Thomas and Jamison (1975) reported normative developmental data which led them to conclude that girls lag behind boys in the understanding that the surface of still water remains invariantly horizontal. The most controversal aspect of Thomas's research was his contention that this lag is so great that, whereas the majority of boys had a firm grasp of this principle by the seventh or eighth grade, "50% of college women still do not know the principle and they don't readily learn it in tasks designed to optimize self discovery" (Thomas, 1973, p.173). The developmental sequence reported by Thomas with respect to his male subjects follows quite well from predictions made by Piaget and Inhelder. The performance of the females on the other hand is quite incompatible with Piagetian theory. At this point it is important to realize two important considerations with respect to the research dealing with the development of horizontality in children: 1. There is no indication in the data reported by Piaget and Inhelder that any of their subjects were girls; 2. Although there have been fairly comprehensive studies lending support to Piaget's theory of conservation of horizontality (Smedslund, 1963; Beilin, Kagan, & Rabinowitz, 1966; Barna & O'Connell, 1967; Ford, 1970), previous to Thomas's research there was no suggestion that girls and boys differ in their acquisition of horizontality. Whether this failure to report sex differences reflects either no such finding in these developmental studies, or results from a pooling of the male and female samples in the data analysis, is not known.

Thomas's conclusion that college women perform poorly in horizontality because of a conceptual deficit seems to be largely based upon three findings. First, when the real water in the model was visible, subjects made correct water line adjustments in the pretend bottle. Second, when subjects were interviewed as to the rationale behind their responses in the bottle task, those who performed poorly were not able to express a cogent verbal answer stressing that the water should remain level. Frequently these subjects responded that although the water was level when the container was upright, tilting the container resulted in the water surface moving to an oblique position. Third, subjects who performed poorly, if given training designed to elicit the discovery of the correct principle, benefited very little from this training. This finding is important because given that subjects lack the underlying conceptual understanding of the principle, the failure of training to improve performance to any great extent is what would be predicted by Piaget and Inhelder as well as by other research dealing with the development of horizontality in children (Smedslund,1963 and Beilin et al, 1966).

Even though Thomas's conceptual deficit interpretation logically follows from his data it is difficult to accept. Intuitively it seems hard to understand how a college age subject, probably in the upper portion of the IQ distribution, having had high school science courses and having had many years of experience perceiving the invariance of water levels across diverse situations, could possibly not understand the principle that still water remains invariantly level regardless of container orientation.

It was not long before alternate explanations were offered. Willemsen and Reynolds (1973) using a similar apparatus to that of Thomas, investigated sex differences in adults' judgements of horizontality as a function of container shape. They hypothesized that the reason women performed poorly in horizontality tasks resulted from the greater tendency of women to be influenced by straight-line characteristics of the containers used in previous research. Willemsen and Reynolds presented to college age subjects containers with varying degrees of straight line characteristics. The results showed that when subjects were asked to predict the water level in a circular container, as opposed to a cylindrical shampoo bottle, the difference between the error scores of men and women was greatly reduced. In fact with the circular container there were no significant sex differences present.

A similar interpretation to that of Willemsen and Reynolds was offered by Perper and Chase (1974) in their scathing attack upon the methodology used by Thomas. Perper and Chase stressed the perceptual difficulties subjects are confronted with when presented with Thomas's apparatus. First, if subjects were not seated at eye-level with the water surface in the container (model) but were looking down upon it, then the surface of the water would be seen as an ellipse with an undetermined orientation. Add to this the fact that the model and the pretend bottle are perceptually quite different (the water in the model is an array of three dimensional angles, etc. while the mock water line in the pretend bottle is a one dimensional boundary between the red and white parts of a flat disc), and the effectiveness of the apparatus as a teaching device for subjects who do not seem to understand conservation of horizontality is questionable. Second, as suggested by the research of Willemsen and Reynolds, the perceptual qualities of the conservation task seem to be analogous to the phenomenon of field dependence-independence (Witkin et al, 1954). In typical measures developed by Witkin to study field dependence, the subject is required to overcome the influence of the surrounding tilted field in determining the vertical (Rod and Frame Test, RFT) or to separate an item which is embedded in a confusing context (Embedded Figures Test, EFT). The demands placed upon subjects by both of these tests seem to be related to the conservation of horizontality, which requires the subject to disembed the horizontal position of the water line from the oblique field presented by the tilted container. Since women traditionally have been found to be more field dependent than men (Witkin, 1973), this field-dependency interpretation is consistent with the fact that no sex differences are found when the containers are presented in horizontal or vertical positions (Thomas, 1973; Willemsen & Reynolds, 1973), or when the straight line characteristics of the containers are minimized (Willemsen & Reynolds, 1973).

Rationale for the Present Research.

In light of the growing body of evidence suggesting that field dependence may be involved in conservation of horizontality tasks, the present research was designed to test the hypotheses that a) field effects affect performance on these tasks, and that b) these effects may account for a significant portion of the discrepancy found between male and female performance on horizontality tasks. Although ideally this would best be achieved with an apparatus similar to that used by Thomas, it was felt that valuable paper and pencil data could be collected during the substantial amount of time required to build the apparatus.

EXPERIMENTS 1a and 1b.

Experiments 1a and 1b were paper and pencil studies utilizing a Cue-No Cue variable as the method by which field effects could be manipulated. While subjects in the Cue condition received drawings of the bottles with false water lines which misrepresented what the water level should actually look like, subjects in the No Cue condition received drawings with no water levels drawn in. The logic of this procedure follows from an effort to make the paper and pencil Cue condition as similar as possible to Thomas's methodology, recognizing certain parallels between the Witkin (RFT) and Thomas methodologies in terms of the perceptual demands made upon subjects. In both types of research the subject is required to generate the correct solution from an initially incorrect one. Witkin in his RFT research begins each trial with both the rod and the frame set to some oblique position. Similarly, Thomas begins each horizontality trial with both the bottle and the mock water line at various degrees of tilt.

As a result of the suspected relationship between tasks that measure field dependence and those that measure conservation of horizontaltiy, it was expected that women, being more field dependent than men, would be more misled by the presence of conflicting cues than would the men.

EXPERIMENT 1a.

Method

Subjects

The subjects were 26 male and 22 female senior high school students (grades 11 and 12) enrolled at Carson Graham high school. Their average age was 16.5 years. Sampled were two grade 11 and two grade 12 English classes. Since English at this school was a compulsory subject for students planning to enter a college or university, it was felt that these classes would provide a more or less random sample of the upper levels university entrance population.

Apparatus

Subjects received stimulus booklets containing drawings representing bottles at various degrees of tilt. Each booklet contained eight bottle orientations corresponding to the following numeral clock positions: 1, 2, 4, 5, 7, 8, 10, and 11 o'clock. There was one 10 x 4 cm drawing per page (see Appendix A). For each booklet the order of the various bottle orientations was randomized. The first page of each booklet contained a picture of a bottle, half full of water, standing "straight up" (90 degrees to the bottom of the page). In addition, the following instructions were given on the first page of booklets representing the No Cue (Q0) experimental condition:

> Starting on the next page, this bottle is tipped in a number of different ways. Would you please predict where you think the water would be by drawing in the water line for each bottle.

Booklets for the Cue (Q33x60) condition were constructed in a similar fashion except that each bottle also contained a drawn in 'false' water line. These water lines were false in that they misrepresented where the water would be, if in reality a half full bottle of water was tilted to the various angles. Bottles at 1, 4, 7, and 10 numeral clock positions contained water lines deviating by 33 degrees from the correct solution (horizontal as determined by the bottom of the page), while those at 2, 5, 8, and 11 o'clock positions contained water lines deviating by 60 degrees. Subjects in this experimental condition received the following instructions on their first page:

> Starting on the next page this bottle is tipped in a number of different ways. For each bottle the water line is drawn in.

1.) If you agree with where the water line is drawn, put a check mark (✓) beside it and go onto the next page.

2.) If you disagree with where the water line is drawn, predict where the water should be, by drawing in your own water line.

In addition, all subjects were required to give their sex and grade at the beginning of the booklet.

Procedure

The booklets were distributed in four one hour 'University Entrance' English classes. After being introduced to the classrooms the experimenter proceeded to hand out the booklets. Since there was no way of knowing the number of students that would be in attendance in each classroom, the booklets were arranged such that the two experimental conditions alternated. In this way it was hoped that, in addition to random assignment of subjects, each of the experimental conditions would result in comparable numbers of subjects.

Results

The data were scored by extending each subject's response line to the edge of the sheet and then with a protractor measuring the angle between this line and the bottom of the page. Errors were measured in terms of absolute degrees of deviation from the horizontal and thus could range from 0 degrees to 90 degrees. These data were transformed by the logarithm of the score plus one (y'=log(y+1)).[1] The purpose of this transformation was to break a high dependence between treatment means and standard deviations (Myers, 1972). Since there were unequal numbers of subjects in the various treatment combinations it was not feasable to analyze all the data gathered. Thus 12 subjects (four subjects from each of the three 'oversized' between-Ss cells) were randomly selected and not included in the analysis. An overall four-way mixed analysis of variance (2x2x4x2) was then performed upon the transformed scores of the remaining 36 subjects. There were two between-Ss sources: Sex(X) and Cue(Q), and two within-Ss factors: Bottle orientation(B) and Direction of tilt(H). All four factors were treated as fixed. Since the between-Ss sources were of primary interest in this experiment, it was important to analyze the data for the total number of subjects, regardless of the unequal 'n' problem. Thus an unweighted means

1. Mean errors shown in tables or graphs were arrived at by taking anti-logs of the transformed data means in question and then subtracting one (y=exp(y')-1).

analysis (Myers, 1972) was performed upon the between-Ss sources. The analysis of variance F tests were then adjusted appropriately.

The analysis of variance summary table is presented in Table 1. The analysis revealed that, although the main effects due to sex and bottle orientation were significant, they were both present in higher order interactions. Both the sex by cue (XQ) and sex by bottle (XB) interactions were found to be significant. The sex by cue interaction is displayed in Figure 1 and shows that the females performed more poorly than males when there was a conflicting cue present but not when conflicting cues were absent. The sex by bottle interaction is presented in Figure 2.[2] Although females made more errors than the males at all bottle orientations, this sex difference was maximized at the four and eight o'clock bottle orientations.

2. In this graph clock symmetric angles have been pooled together (11+1, 10+2, etc.). The rationale for this procedure is twofold: a) Previous research (Thomas, 1975) has suggested that direction of tilt is unimportant; b) In the present research the direction of tilt factor is only significant in the form of a three-way interaction between sex, bottle orientation and direction of tilt ($F=3.35$, $df=3/96$, $p<.025$, $\hat{\omega}^2=.0595$). This interaction is not readily explained, and does not add to the explanatory power of the results.

Table 1

Experiment 1a
Analysis of Variance Summary

Source	df	MS	F	Error term	Variance estimate
Sex (X)	1	32.2017	6.8941*	S(XQ)	.17202
Cue (Q)	1	2.5047	.5362	S(XQ)	.01337
Bottle orientation (B)	3	3.9037	4.7490**	SB(XQ)	.04280
Direction of tilt (H)	1	.1930	.3775	SH(XQ)	0.0
XQ	1	37.5916	8.0480**	S(XQ)	.40162
XB	3	3.0960	3.7664**	SB(XQ)	.06317
QB	3	.3994	.4858	SB(XQ)	0.0
XH	1	.0000	.0000	SH(XQ)	0.0
QH	1	.5894	1.1527	SH(XQ)	.00108
BH	3	.7309	1.6025	SBH(XQ)	.00763
S(XQ)	44	4.6709			.56501
XQB	3	.5022	.6110	SB(XQ)	0.0
XQH	1	.3184	.6227	SH(XQ)	0.0
XBH	3	1.5274	3.3490*	SBH(XQ)	.05952
QBH	3	1.0891	2.3880	SBH(XQ)	.03517
SB(XQ)	96	.8220			.41100
SH(XQ)	32	.5113			.12782
XQBH	3	1.0377	2.2752	SBH(XQ)	.06462
SBH(XQ)	96	.4561			.45607

* $p<.025$
** $p<.01$

Note Although summary statistics for the between-Ss sources are based upon the total number of 48 Ss, any sources which contain a within-Ss factor are based upon 36 Ss.

Figure 1

Study 1a Mean Error Scores of Males and Females as a Function of the Presence or Absence of False Cues

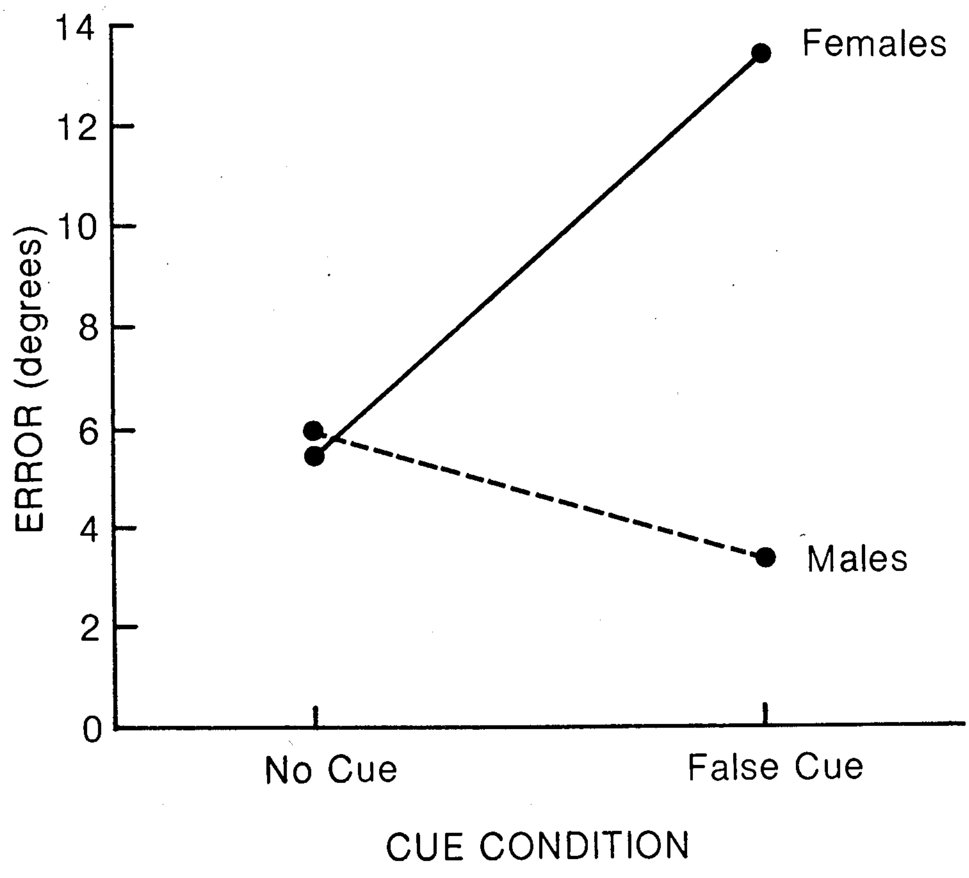
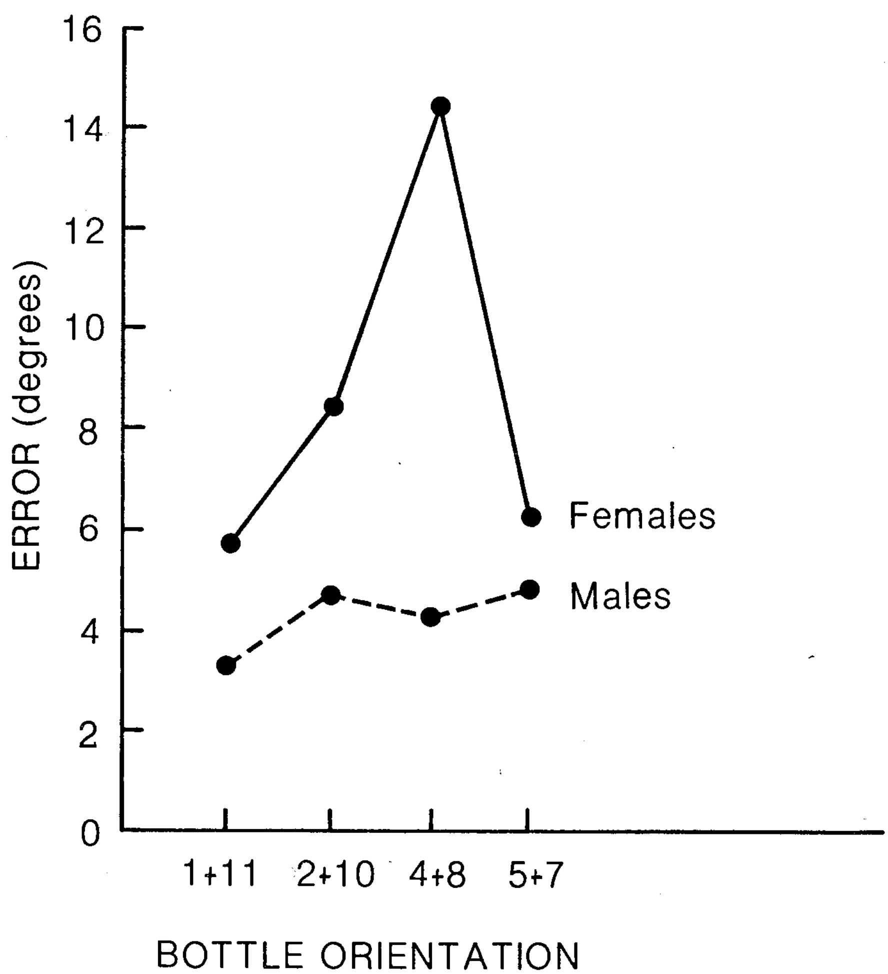


Figure 2

Study 1a Mean Error Scores of Males and Females as a Function of Pooled Clock-Symmetric Bottle Orientations.



EXPERIMENT 1b

This study was designed primarily as a replication of experiment 1a with a university population. In addition, since in study 1a the orientation of the false water line was confounded with bottle orientation and direction of bottle tilt, the present experiment was designed to allow for a clearer analysis of these variables. This was accomplished by the addition of two extra cue conditions, which allowed the tilt of the false water line to be treated as a between-Ss variable crossed with both bottle orientation and direction of bottle tilt.

Method

Subjects

The subjects were 73 male and 85 female introductory psychology students enrolled at Simon Fraser University.

Apparatus

Subjects received stimulus booklets which were constructed in a similar fashion to those used in study 1a. Again each booklet contained a random sequence of the eight possible orientations (1,2,4,5,7,8,10, and 11 o'clock).

In addition to the No Cue (Q0) experimental condition there were this time three Cue conditions containing 'false' water lines. The Q33x60 condition was the same as that used in study 1a. Bottles at 1, 4, 7, and 10 numeral clock positions contained water lines deviating by 33 degrees from the horizontal, while those at 2, 5, 8, and 11 o'clock positions contained water lines deviating by 60 degrees. In the Q33 condition all bottles contained water lines deviating by 33 degrees from the horizontal, while bottles in the Q60 condition contained water lines deviating by 60 degrees. The Q33 and Q60 conditions were added to the procedure to allow for a clearer analysis of the water tilt factor than was possible in study 1a.

All subjects were required to give their sex and year of study at the beginning of the booklet.

Procedure

The booklets were distributed at the beginning of an introductory psychology lecture. The lecture did not begin until the booklets were completed and collected. Prior to distribution the booklets were arranged such that the four experimental treatments alternated. This was done in an effort to achieve random and balanced assignment of subjects among the experimental treatments.

Results

The data were scored in the same fashion as for study 1a. Again a logarithmic transformation was performed upon the raw data, and anti-logs were used to 'back-transform' means presented in tables or graphs. The transformed scores were analyzed with a four-way mixed analysis of variance (2x4x4x2). There were two between-Ss factors: Sex(X) and Cue(Q), and two within-Ss factors: bottle orientation(B) and direction of tilt(H). All factors were treated as fixed. As in Experiment 1a, since there were unequal numbers of subjects in the various treatment combinations this necessitated that 30 subjects be randomly rejected from the complete analysis. The overall analysis of variance was thus performed upon the remaining 128 subjects. Because of the importance of the between-Ss sources, the F tests for these were again adjusted with the unweighted means technique and thus represent the total 158 subjects.

The analysis of variance summary is presented in Table 2. As in study 1a, the main effects due to sex and bottle orientation were significant. The means for these effects are

Table 2

Experiment 1b
Analysis of Variance Summary

Source	df	MS	F	Error term	Variance estimate
Sex (X)	1	75.7937	14.8228***	S (XQ)	.12190
Cue (Q)	3	3.0500	.5964	S (XQ)	.00981
Bottle orientation (B)	3	3.9570	5.7595**	SB (XQ)	.01277
Direction of tilt (H)	1	.2011	.4047	SH (XQ)	0.0
XQ	3	4.7222	.9235	S (XQ)	.03038
XB	3	.5157	.7505	SB (XQ)	0.0
QB	9	1.2719	1.8513	SB (XQ)	.00914
XH	1	.1214	.2443	SH (XQ)	0.0
QH	3	1.6033	3.2263*	SH (XQ)	.00864
BH	3	1.9642	2.8856	SBH (XQ)	.01003
S (XQ)	150	5.1133			.63737
XQB	9	.7455	1.0851	SB (XQ)	.00183
XQH	3	.1602	.3223	SH (XQ)	0.0
XBH	3	.7662	1.1257	SBH (XQ)	.00134
QBH	9	1.0243	1.5049	SBH (XQ)	.01074
SB (XQ)	360	.6870			.34352
SH (XQ)	120	.4970			.12424
XQBH	9	.7913	1.1625	SBH (XQ)	.00691
SBH (XQ)	360	.6807			.68067

* $p<.05$
** $p<.005$
*** $p<.001$

Note Although summary statistics for the between-Ss sources are based upon the total number of 158 Ss, any sources which contain a within-Ss factor are based upon 128 Ss.

shown in Figures 3 and 4 respectively. Females made more errors than males across all conditions, and the 4 and 8 o'clock bottle orientations resulted in the greatest errors for both sexes. In addition, the two-way interaction between cue(Q) and direction of tilt(H) was found to be significant. Although an attempt was made to explain this interaction this proved to be a very confusing task. Since the result was quite small (both in terms of variance accounted for and F value) it was decided that even if a good explanation was possible it would not add to the explanatory power of the overall analysis.

Even though in the analysis of variance the sex by cue interaction was not significant, inspection of Figure 3 reveals that the trend is similar to that found significant in study 1a. As a result of this the data from the two studies were pooled. Since study 1a did not contain the Q33 or Q60 conditions these data from study 1b were not included. To take into account the unequal numbers of subjects in the design, the pooled transformed data were analyzed with an unweighted means analysis (2x2x2). The three factors experiment(E), sex(X), and cue(Q) were all between-Ss factors and were treated as fixed. This analysis disregards the possible within-Ss sources by collapsing over them and in effect treating each individual subject's eight predictive adjustments as an average score.

Figure 3
Study 1b Mean Error Scores of Males and Females as a Function of Cue Condition

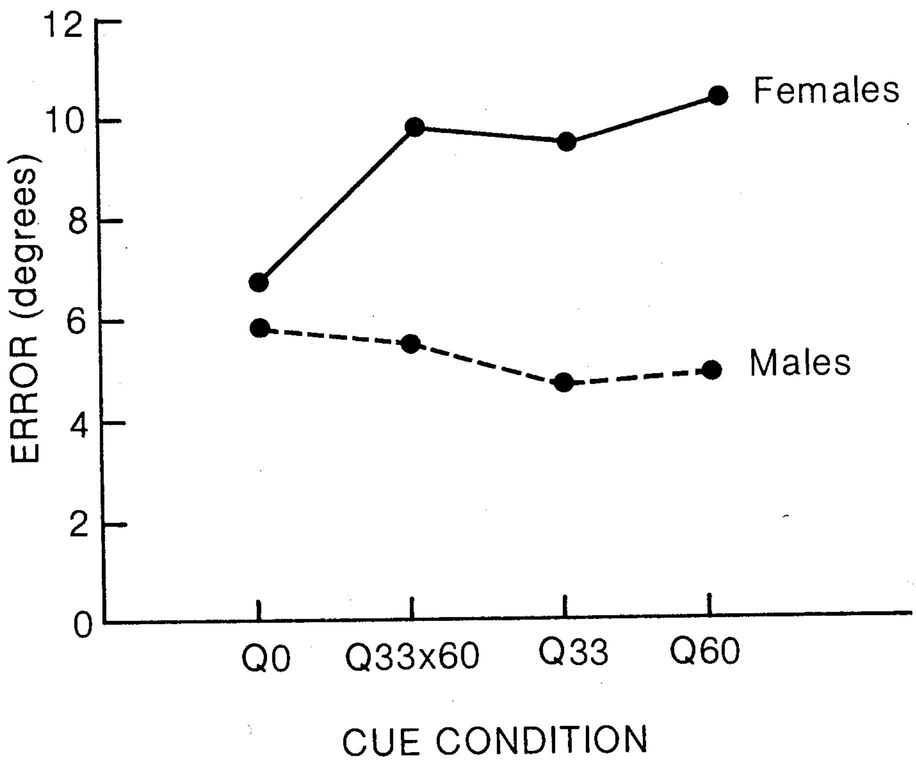
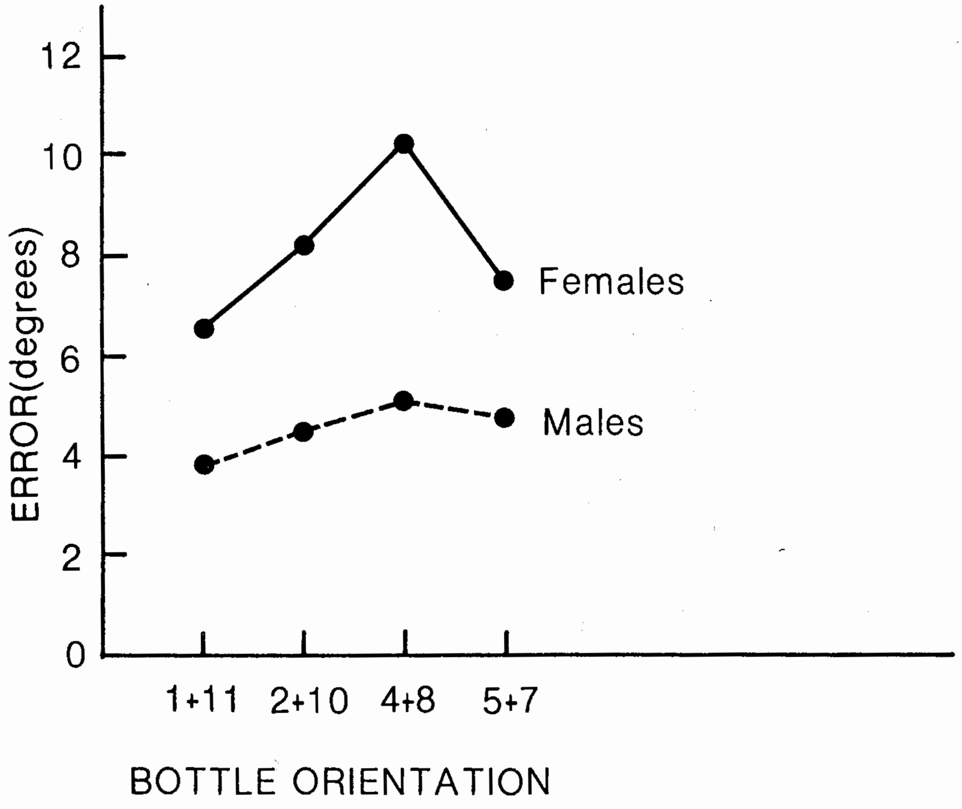


Figure 4

Study 1b Mean Error Scores of Males and Females as a Function of Pooled Clock-Symmetric Bottle Orientations



The analysis summary is presented in Table 3. Both the sex main effect and the sex by cue interaction were found to be significant. It is important to note that the three-way interaction between experiment, sex, and cue is not significant. This is what allows pooling of the data from both studies to get a better estimate of the sex by cue condition interaction. This interaction is plotted in Figure 5 and shows that when conflicting cues were present the females made significantly greater errors than did males.

Discussion of Experiment 1a and 1b.

The results of these experiments are compatible with previous horizontality research discussed in the introduction. As suggested by Rebelsky (1964) and Barna and O'Connell (1967), both the present experiments show that when using containers tilted at 30 degrees (1 and 11 o'clock or 5 and 7 o'clock) and 60 degrees (2 and 10 o'clock or 4 and 8 o'clock) from the perpendicular, subjects make greater errors on those tilted at 60 degrees. Interestingly, experiment 1a revealed that this variable (bottle orientation) affected the performance of females more than that of the males. Even though all subjects found the 4 and 8 o'clock positions most difficult the women especially did so. This finding does lend some support to Rebelsky's study where she found a sex difference in

Table 3

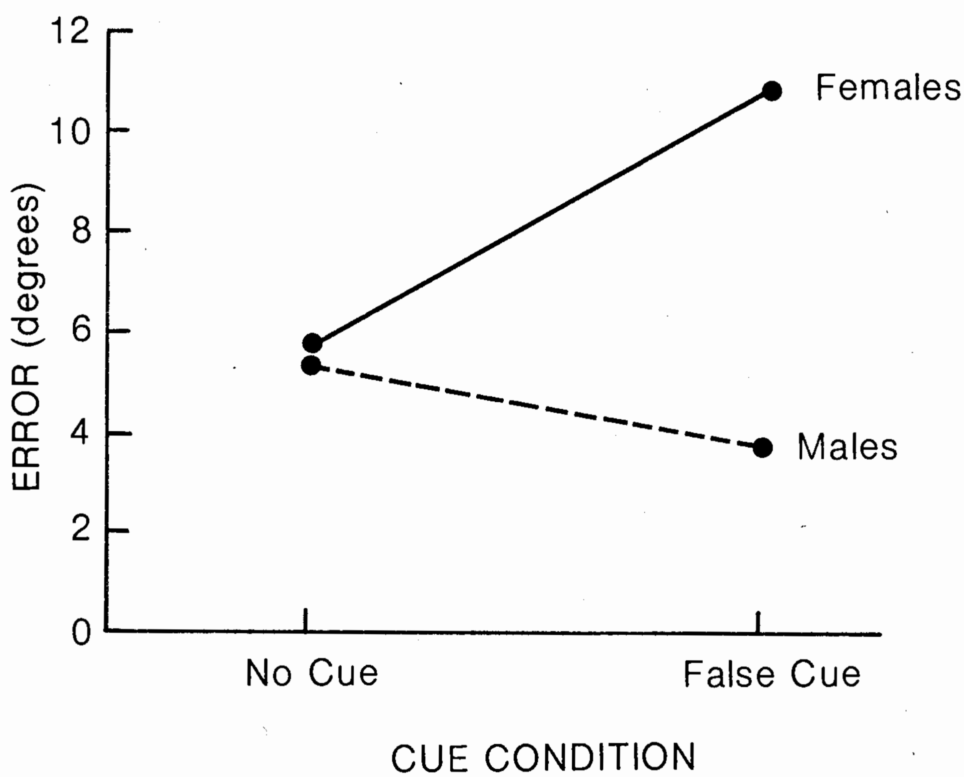
Experiment 1a and 1b
Combined Analysis of Variance

Source	df	MS	F	Error term	Variance estimate
Experiment(E)	1	.2607	.061	S(EXQ)	.00056
Sex(X)	1	51.8720	11.924**	S(EXQ)	.11208
Cue(Q)	1	5.9681	1.372	S(EXQ)	.01289
EX	1	2.9600	.680	S(EXQ)	.01279
EQ	1	.0021	.001	S(EXQ)	.00001
XQ	1	42.5056	9.770*	S(EXQ)	.18368
EXQ	1	9.7402	2.239	S(EXQ)	.08418
S(EXQ)	117	4.3500			

* $p<.005$
** $p<.001$

Figure 5

Mean Error Scores of Males and Females as a Function of the Presence or Absence of False Cues (Studies 1a and 1b pooled)



performance on 60 degree tilts but not on 30 degree ones. In experiment 1b, the same trend was present (Figure 4), but it was not significant.

As expected, both studies show a significant sex difference with females performing more poorly than males. The most important finding with respect to this sex difference was that when false water lines were not included, differences in error scores between males and females were minimized. This result suggests that the females were more misled by the presence of conflicting cues than were the males. Although this result is contradictory to Morris's (1971) study where he failed to substantiate a field dependency hypothesis, there is an important difference between the function of Morris's additional cue condition and the one employed in the present research. Whereas Morris attempted to use the additional cue (a horizontal line drawn below the tilted container) as an aid for a field dependent subject, the present experiments utilized the additional cue (an oblique line drawn within the tilted container) to misrepresent what the water level would actually look like in the real world. As discussed previously, this procedure was utilized as a result of certain parallels between the Witkin and Thomas methodologies and thus probably tapped into perceptual field effects which lead women to perform more poorly than men on these types of tasks.

EXPERIMENT 2

Although experiments 1a and 1b revealed that field effects possibly related to Witkin's concept of field dependence-independence affect performance on the conservation task, Thomas and Jamison (1974,1975) have claimed that the water-level task is quite different from Witkin's RFT for measuring field dependence. First, when specifically instructed to do so, subjects have no trouble in setting the water line to the horizontal, whereas in the RFT this type of a response is exactly what subjects are incapable of doing. Second, while the RFT is administered in a completely dark room, the horizontality task is administered in a normally illuminated room with numerous horizontal cues.

During the preparation of experiment 2, papers presented by Harris, Hanley and Best (1975) and Liben (1975) had a great deal of influence on the design of this study and the overall interpretation of the results. Harris et al performed a series of paper and pencil studies where subjects were required to recognize the correct solution (one that conserved horizontality) from a number of incorrect ones. The usual sex difference in performance emerged. In addition Harris et al showed that by varying parameters in the instructions they could minimize differences in error scores between men and women. The authors concluded that 29% of the women and 45% of the men conserved horizontality even when instructions were specifically designed to discourage it (by specifically stating that both the bottle and the liquid within it were in motion), while a small portion of men and women performed poorly even when instructions were aimed at encouraging horizontality answers (by specifically stating that both the bottle and the liquid within it were stable and not in motion). In discussing their results, Harris et al suggest that it may be incorrect to think of conservation of horizontality strictly in terms of a milestone in logical or analytical thinking. Their final conclusion suggested that "the horizontality test may well be primarily a test of visuo-spatial ability" (p.13), a skill at which males have traditionally excelled.

A factor analytic study by Liben (1975) investigated the possible relationship between the horizontality test (paper and pencil) and the embedded figures test (EFT) as well as various other more general cognitive measures. The study was carried out with high school students and revealed that the conservation of horizontality task was related to both the EFT ($r=-.57$) and spatial ability ($r=.52$) as measured on the Differential Aptitude Test. (The negative correlation results from the scoring procedure utilized by Liben. A high score on the Horizontality Test indicates better performance, whereas a high score on the EFT indicates poorer performance.)

Rationale for Experiment 2

Although the conservation of horizontality task places numerous demands upon subjects, it is possible to conceive of the task as involving two major components. The first phase involves the recognition or generation of the principle that still water remains level, and the second phase is the actual performance of the correct response by indicating that the water should be horizontal. When a subject performs poorly upon the task it is not clear whether he or she does not understand the principle or simply has difficulty in producing the horizontal in the presence of conflicting cues. Although Thomas and Jamison (1974,1975) have claimed that the latter possibility is not likely, they present no data to support their conclusion. With evidence accumulating that conservation of horizontality tasks involve perceptual components related to visuo-spatial skills such as those involved in field dependence-independence, it was decided to look directly at what role these might play in a typical conservation of horizontality paradigm, but one where subjects are specifically instructed to set the water line to the horizontal.

Method

Subjects

The subjects were 32 male and 32 female students enrolled in introductory psychology classes at Simon Fraser University. All subjects were paid for their participation.

Apparatus

Bottle Test(BT). A Thomas type of apparatus was utilized in this study. Since only the perceptual components of the task were being evaluated, subjects were presented only with the 'pretend' bottle. This was a rectangular bottle (sectioned along the longitudinal axis) 17.5 cm high and 8 cm wide mounted upon an adjustable disc, 27.5 cm in diameter. Although it has no real liquid in it, the subject saw a mock water line and the bottle appeared to be half full. This was accomplished by placing behind the pretend bottle, but visible through it, a half red half white rotatable, 24 cm in diameter disc. It was this disc that the subject rotated in order to predict the position of the water at any given orientation of the bottle. The accuracy of the prediction was measured by a three-arm protractor affixed to the back of the apparatus but not visible to the subject.

Rod and Frame Test (RFT). The RFT apparatus employed was a portable version which consisted of a rod (19 cm by 3 mm) surrounded by a square frame, each side of which was 19 cm long by 3 mm wide. Both the rod and frame were painted with white paint upon individual clear glass discs mounted one in front of the other in such a way that they could be rotated independently. The rod and frame, which were surrounded by a completely black housing, could be illuminated with a small black light concealed within the apparatus. Although the rod and frame would then appear quite luminous other parts of the apparatus could not be seen.

Procedure

Each subject was tested individually. Following arrival the subject was seated in front of the apparatus. The height of the subject's chair was adjusted so that the subject sat at approximately eye level with the pretend water line. The subject was then given the following instructions:

> I will turn this adjustable bottle to 14 different positions. I will also turn the adjustable line to various positions. What I want you to do is to set the line to the horizontal. By horizontal I mean absolute horizontal parallel with the ground.

At this point the subject was asked if he or she needed any clarification about the procedure and was allowed to experiment with the equipment.

Each subject received 14 trials on the Bottle Test (BT). Twelve trials presented the pretend bottle at each of the 12 angles corresponding to the hours of the clock. In addition there was a repetition of the 12 and 6 o'clock positions to allow for ease of statistical analysis. The 14 positions were arranged into four randomly chosen sequences. The rationale for this was that there was no a priori reason why sequence of presentation should make any difference. Subjects were randomly assigned to the four sequences with care being taken that sex and number of subjects were balanced among the sequences. The orientation of the pretend water line was randomized (with the restriction that it should deviate from the horizontal by a minimum of 33 degrees) for each subject at the beginning of each trial.

After 32 subjects had completed the BT it was decided that it would be profitable to compare performance on the bottle test to performance on the Rod and Frame Test(RFT). As a result of this, the next 32 subjects were tested with both the bottle apparatus and the RFT. (Although there was no reason to believe that this switch in methodology would in any way affect the bottle test performance of the last 32 subjects, a testing session variable (T) was included in the data analysis to check for this possibility.) After the subject received the 14 trials on the bottle apparatus, the unit was removed and in its place was positioned a covered RFT unit. The subject was seated in an upright position 180 cm from the RFT. The apparatus was uncovered and the subject received the following instructions:

> In this part of the experiment I will turn this rod (pointing to the rod) and this frame to various orientations. There will be 8 trials and for each trial I will slowly turn the rod towards the vertical. Your task is to tell me when the rod is vertical, i.e. absolute vertical with the real world.

At this point the subject was asked if he or she needed any clarification about the procedure.

Each subject received 8 trials on the RFT apparatus. The positioning sequence of both the rod and frame is shown in Appendix B. The experimenter moved the rod in two degree increments with a pause of approximately one second between moves. The experimental room was completerly dark, with care taken that all extraneous light sources be blacked out. Between trials a small light was used so that the experimenter could record the trial data. This light also helped to slow down subject's dark adaptation. This was important since the RFT unit emits enough black light that a totally dark adapted subject can make out some of the objects in the chamber.

RESULTS

Bottle Test Data. The data were scored by measuring absolute degrees of deviation from the horizontal. The error scores were then analyzed with a five-way mixed analysis of variance (2x2x4x7x2). The three between-Ss factors were: testing session (T), sex (X), and presentation sequence (C), while the two within-Ss factors were: bottle orientation (B) and direction of tilt (H). Presentation sequence was treated as a random factor while the remaining factors were treated as fixed.

The analysis of variance summary is presented in Table 4 and shows that both the main effect due to bottle orientation and the sex by bottle orientation interaction were significant. These effects are displayed in Figure 6 and reveal that when the bottle was inclined to the 5 (or 7) and 1 (or 11) o'clock orientations subjects, especially females, performed substantially poorer.

Table 4

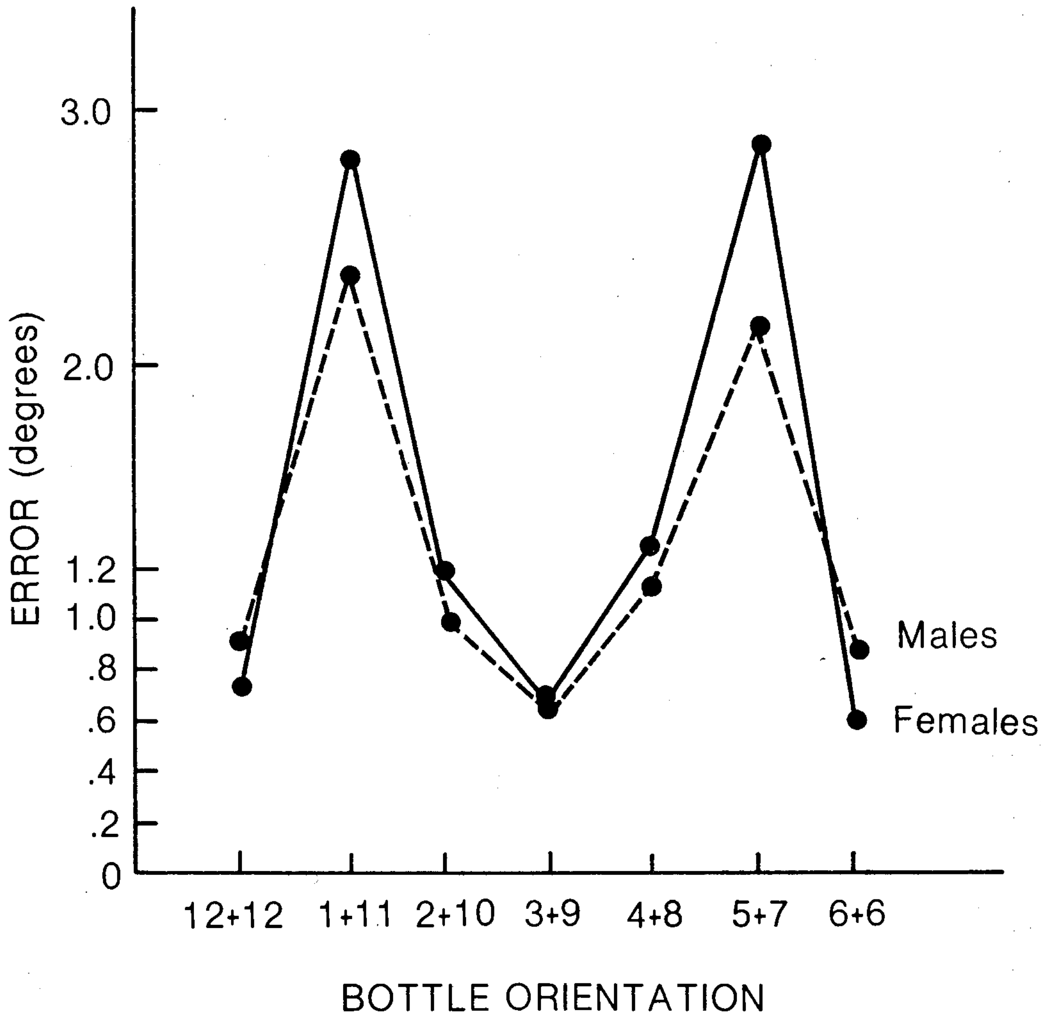
Experiment 2
Analysis of Variance Summary

Source	df	MS	F	Error term	Variance estimate
Testing session (T)	1	2.9029	1.9931	EC	.00323
Sex (X)	1	4.7154	3.0802	XC	.00711
Sequence (C)	3	2.6231	1.4026	S (EXC)	.00336
Bottle orientation (B)	6	88.0806	54.7953***	CB	.67557
Direction of tilt (H)	1	.0100	.0568	CH	0.0
EX	1	12.7779	2.5843	EXC	.03497
EC	3	1.4565	.7788	S (EXC)	0.0
XC	3	1.5309	.8186	S (EXC)	0.0
EB	6	.3977	.3744	ECB	0.0
XB	6	3.8195	8.6738***	XCB	.05280
CB	18	1.6074	1.2893	SB (EXC)	.01127
EH	1	.0100	.0232	ECH	0.0
XH	1	.5904	.4675	XCH	0.0
CH	3	.1767	.2367	SH (EXC)	0.0
BH	6	1.8955	1.5341	CBH	.01031
EXC	3	4.9445	2.6439	S (EXC)	.05900
EXB	6	.8402	.4959	EXCB	0.0
ECB	18	1.0622	.8520	SB (EXC)	0.0
XCB	18	.4404	.3532	SB (EXC)	0.0
EXH	1	.4922	3.9976	EXCH	.00330
ECH	3	.4327	.5795	SH (EXC)	0.0
XCH	3	1.2630	1.6917	SH (EXC)	.00922
EBH	6	1.1661	2.1305	ECBH	.01933
XBH	6	1.4079	1.9568	XCBH	.02151
CBH	18	1.2356	1.1194	SBH (EXC)	.00821
S (EXC)	48	1.8701			.13358
EXCB	18	1.6945	1.3591	SB (EXC)	.05595
EXCH	3	.1231	.1649	SH (EXC)	0.0
EXBH	6	1.2159	.6758	EXCBH	0.0
ECBH	18	.5473	.4959	SBH (EXC)	0.0
XCBH	18	.7195	.6518	SBH (EXC)	0.0
SB (EXC)	288	1.2468			.52342
SH (EXC)	48	.7466			.10666
EXCBH	18	1.7991	1.6300	SBH (EXC)	.17374
SBH (EXC)	288	1.1038			1.10420

*** $p<.001$

Figure 6

Study 2 Mean Error Scores of Males and Females Across Pooled Clock-Symmetric Bottle Orientations.



Rod and Frame Test Data. The RFT data were scored in absolute degrees of error from the true vertical and averaged across trials. As expected, females made significantly more errors than the males ($t=4.2841$, $df=30$, $p<.001$).

To compare the Bottle Test performance to that on the RFT, each subject's BT data was averaged across the eight oblique (1,2,4,5,7,8,10, and 11 o'clock) bottle orientations and across the six vertical-horizontal (12,12,3,6,6, and 9 o'clock) bottle orientations. Each subject thus had three mean scores: RFT, BT oblique bottles and BT vertical-horizontal bottles. The relationship among these variables was evaluated by performing Pearson correlations between paired combinations for males and females separately. The analysis summary is presented in Table 5 and shows that for both males and females performance on the BT oblique bottle orientations correlated significantly with performance on the RFT. The difference between male and female correlations was tested with a Fisher Z transformation (Hays, 1963) procedure and was found to be nonsignificant.

Discussion Experiment 2

Although previous investigators (Willemsen and Reynolds, 1973; Thomas & Jamison, 1974, 1975) have claimed that when subjects are specifically instructed to set the pretend water

Table 5

Pearson correlation between performance on the RFT and the Bottle Test.

		Males		
		RFT	Oblique bottles	Straight bottles
	RFT	-----	.5195*	-.1051
Females	Oblique bottles	.7410**	-----	.2767
	Straight bottles	.0932	.0130	-----

* p<.025
** p<.001

level to the horizontal position they do so with little difficulty, the present study suggests that this claim may be an oversimplification. The results of experiment 2 reveal that although the errors made by subjects are quite small, there are systematic differences present. The finding that oblique bottle orientations, specifically the 5, 7, 1, and 11 o'clock orientations, are more difficult than ones in a horizontal-vertical orientation, coupled with the high correlation found between performance on the oblique bottle orientations and performance on the RFT, suggests that the visuo-spatial skills required for the solution of these two tasks are quite similar. Given this interpretation a reasonable assumption is that these same visuo-spatial skills determine to some extent performance on the actual conservation of horizontality task where the subject must both generate the rule that the water should be level, and secondly, apply or put it into practise.

An additional result of experiment 2 was the presence of a sex by bottle orientation interaction. The most obvious explanation, as suggested by the discussion in the preceeding paragraph, is that since there is a correlation between performance on the bottle task and the RFT, it would seem reasonable to conclude that women being more field dependent than men, would perform more poorly on the oblique orientations than would men. Although this may be part of the explanation, post hoc analysis of male vs. female performance on oblique as opposed to vertical-horizontal bottles does not reach acceptable levels of significance. Inspection of the data presented in Figure 6 reveals that it is specifically the 5, 7, 11, and 1 o'clock orientations which are the most difficult, especially for women. Why these bottle orientations are found to be most difficult is quite puzzling but a possible explanation may lie in the fact that in these positions the water level when adjusted to the horizontal is quite short in length. Since a common procedure employed by subjects to solve the problem is to try and make the water line parallel to various external horizontal cues (e.g., frame of the apparatus), at the 5, 7, 11, and 1 o'clock orientations this may be more difficult because the short water line does not allow for effective comparison.

Although the sex by bottle orientation interaction appears to be contradictory to Willemsen and Reynold's conclusion that in their study there were no differences in the ability of men and women to set the pretend water line to the horizontal, it seems that Willemsen and Reynolds only analyzed for a sex main effect. Since the sex main effect in the present study was also non significant, at this level of analysis the results from the two studies are quite compatible. Since Willemsen and Reynolds do not present any additional data, further comparisons are not possible. The present finding is also contrary to Thomas and Jamison's (1974, 1975) claim that subjects have no difficulty with this task. However, Thomas and Jamison present no data to support their contention, and thus comparisons to the present study are not at all possible.

Conclusions

The present studies show that the typical conservation of horizontality task relies quite substantially upon skills traditionally associated with visuo-spatial abilities such as those involved in field dependence-independence. Experiments 1a and 1b showed that field effects play a significant role in the conservation of horizontality task, and experiment 2 further revealed that when one eliminates the problem of whether a subject understands the underlying principle (invariance of water level) by specifically instructing subjects to set the water line to the horizontal, perceptual factors such as field dependence-independence are still active in the task performance. Sex differences in performance on the horizontality task do exist but their magnitude depends upon various task parameters such as presence of conflicting cues or bottle orientations employed. In general, variables which make the conservation of horizontality task more difficult result in a greater sex difference. "...like any spatial test, it can be made harder, so that more people fail, or simpler, so that more people do well, though females on average, still find it more difficult than males do" (Harris, 1975, p.13).

Looking at the results from the present studies in conjuction with research by Harris (1975) and Liben (1975), it is difficult to disregard the spatial nature of the task in favour of a purely conceptual interpretation as Thomas has attempted to do. Although one may be hard pressed to formulate a clear distinction between conceptual and perceptual processes, there is a qualitative difference between the argument that a subject does poorly on the conservation of horizontality because he or she does not understand the principle that still water remains horizontal and the argument that many subjects do poorly on the horizontality test because of their inability to deal effectively with the spatial components of the task. The present experiments do not necessarily show that poor performance on the horizontality task is completely a function of spatial ability, but they do show that poor performance is not completely a function of a conceptual deficit.

Although a 'perceptual' interpretation seems to form a necessary part of any full explanation of the discrepancy between male and female perfcrmance on horizontality tasks it is still possible to maintain, as proposed by Thomas, that the sex difference may be primarily due to a lack of understanding of the underlying principle that still water remains level. A possible explanation of how this deficit might develop is suggested by Piaget and Inhelder's (1956) original description of the water level test,

> "...the repeated difficulty in appreciating the material facts ...undoubtedly indicates an inability to evaluate the perceptual data in terms of the orientation of lines and planes, and thereby suggests the failure on the part of co-ordination as such. What indeed is a system of co-ordinates but a series of comparisons between objects in different positions and orientations?" (p.390)

This description implies that effective visuo-spatial ability is a prerequisite for the development of the understanding that still water remains horizontal. Since women have poorer spatial skills than men, whether due to differential socialization (Maccoby, 1966) or to a sex-linked recessive gene (Bock & Kolakowski, 1973), it is possible to argue that their deficiencies in perceiving spatial relations might make it difficult for women to abstract the conceptual principle.

Future Research

Since the present research suggests that perceptual field effects do play a role in conservation of horizontality tasks, a logical extension of the present study would be to evaluate to what degree these field effects determine performance in horizontality tasks.

A possible research strategy would be to investigate the relationship between conservation of horizontality and perceptual measures. The perceptual measures would include the standard Rod and Frame (RFT) and the Bottle Test (BT) in which the subject's task is to specifically set the water level to the horizontal. The design would be a multivariate one with every subject being evaluated with each of the three measures. Each subject on arriving at the experimental room would first receive a series of trials on the conservation of horizontality apparatus (eight trials corresponding to the eight oblique numeral clock positions). After completing this task each subject would be instructed to set the water level to the horizontal for those same bottle orientations. (In both of these tasks the order of presentation would be randomized for each of these tasks and across all subjects.) After completing both the horizontality and the Bottle Test, subjects would then receive the standard Rod and Frame Test (eight trials in a 'blacked out' room).

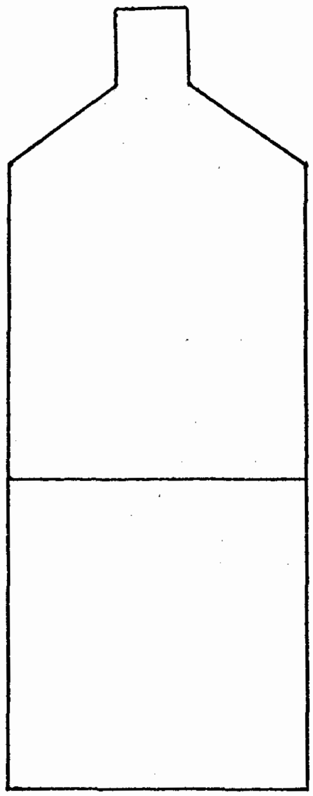
The data could be analyzed using a variety of techniques, with correlational analysis and analysis of covariance being probably the most applicable. Performing Pearson correlations would be a preliminary analysis which would reveal the overall relationship among the three tasks. If as expected the perceptual and horizontality measures are highly related, two separate analyses of covariance could be performed, one treating Bottle Test performance as a covariate while the other treating RFT performance as the covariate. Ideally, the covariance analyses would reveal that if sex differences in performance upon the perceptual measures are taken into account, then the conservation of horizontality task becomes significantly smaller.

Although this type of a design follows directly from the present research its fruitfulness is limited by the underlying assumption that the perceptual and conceptual components of the horizontality task influence performance in an additive fashion. If the majority of their influence is in the form of an interaction, this interaction would be difficult to evaluate. Since the interaction hypothesis is the more likely one the above type of study could be supplemented with various other measures. A potentially fruitful approach would be to interview subjects regarding the principle which governs the appearance of a liquid in a tilted container. In this type of research the interview is important for two reasons. First, it might suggest critical variables or 'demand characteristics' in the experimental situation which have been overlooked previously. Second, the interview can be used to evaluate a subject's understanding of the principle that still water is level while at the same time minimizing the confounding effects of the perceptual qualities of the usual horizontality task.

APPENDIX A

Sample of Stimulus Booklets Used in Experiment 1a and 1b.

Here is a closed bottle half full of water.

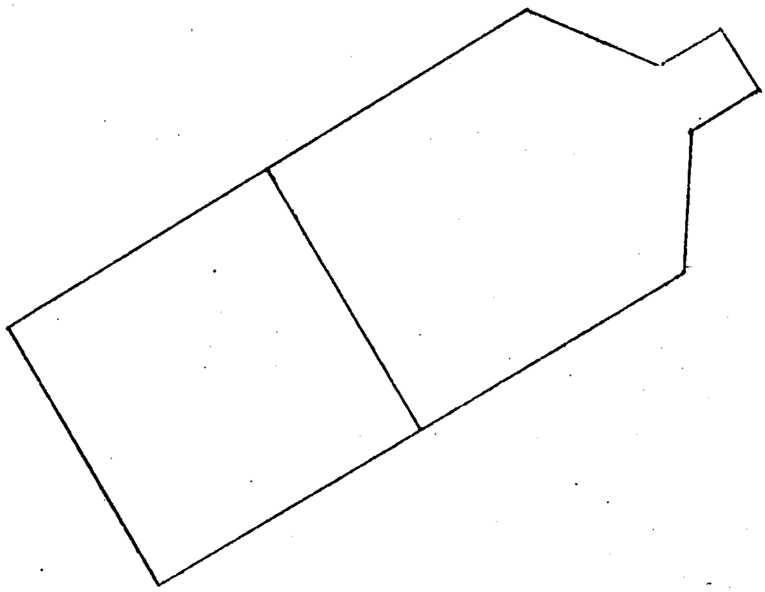


Starting on the next page this bottle is tipped in a number of different ways. For each bottle the water line is drawn in.

1.) If you agree with where the water line is drawn, put a check mark(✓) beside it and go onto the next page.

2.) If you disagree with where the water line is drawn, predict where the water should be, by drawing in your own water line.

APPENDIX A (Cont'd)



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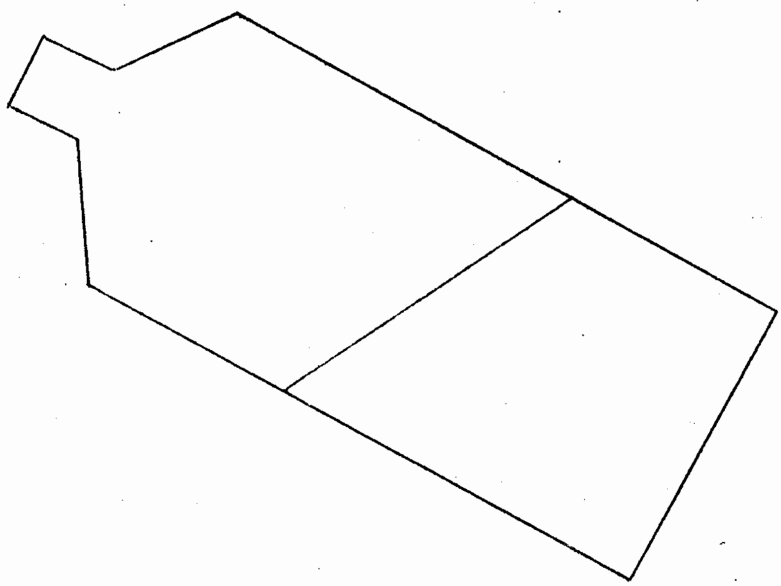

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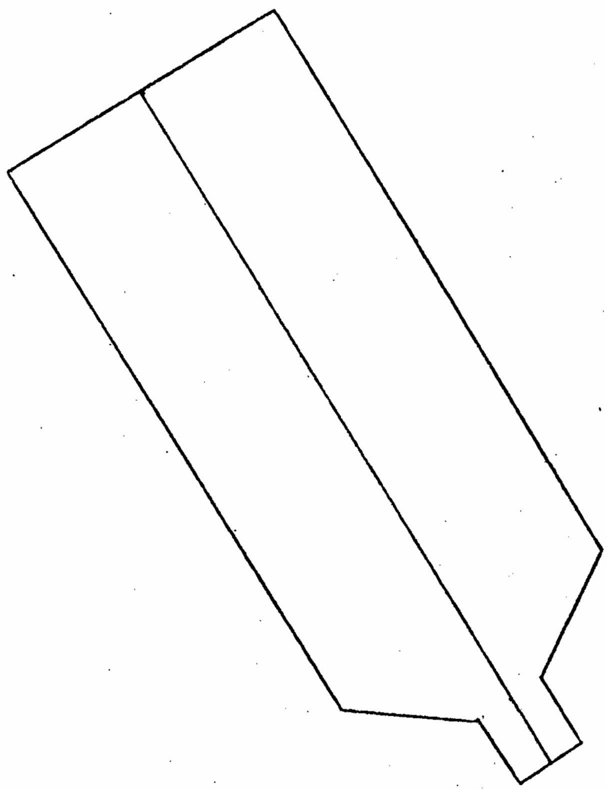

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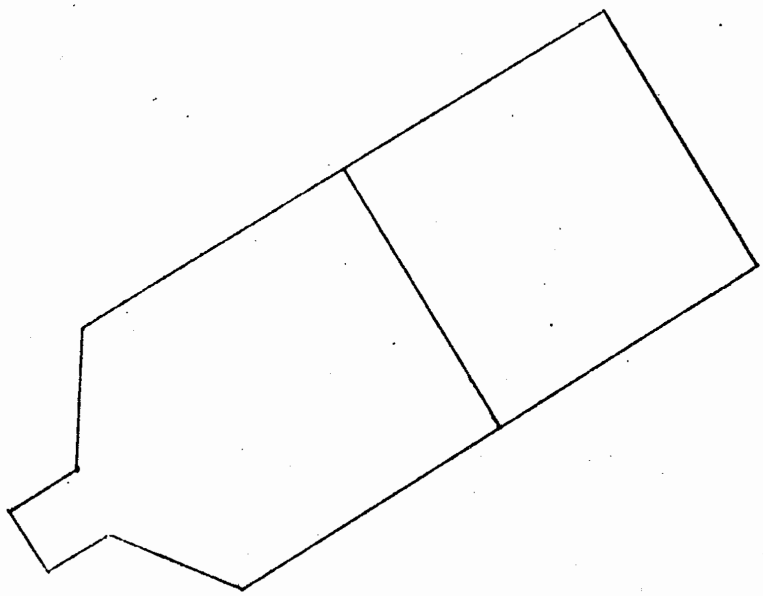

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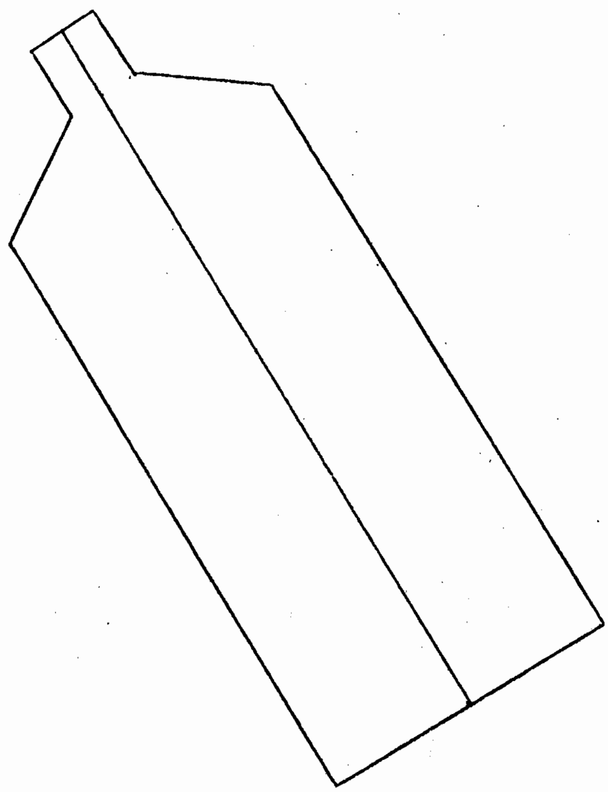

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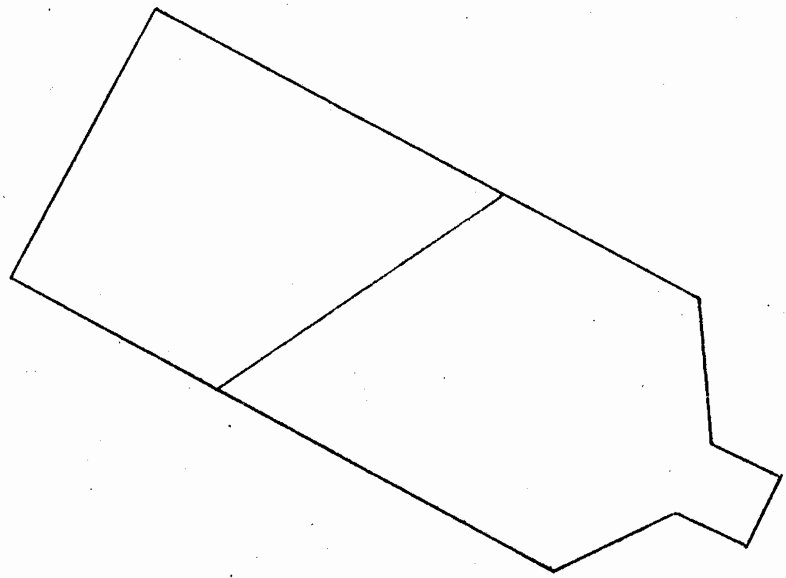

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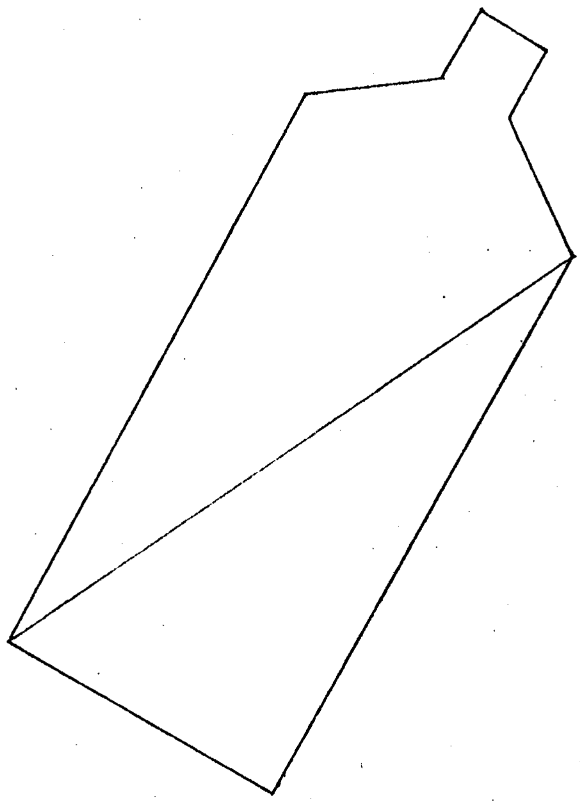

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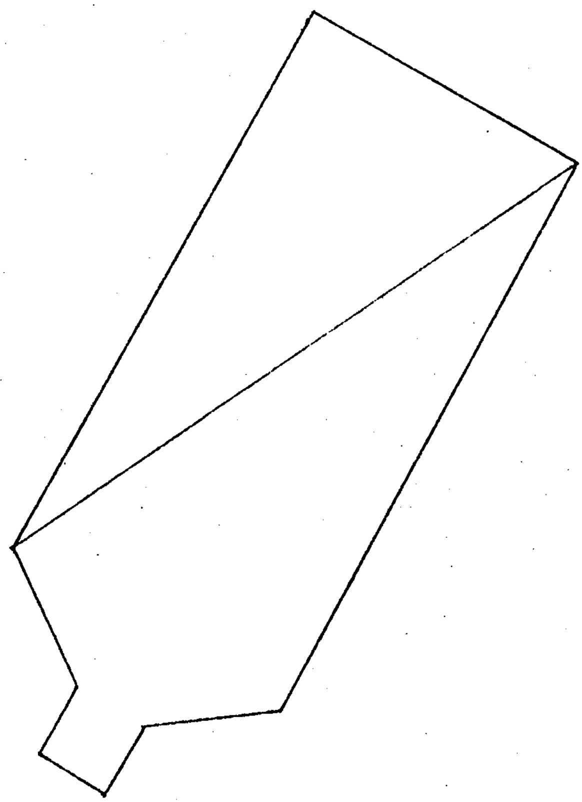

APPENDIX B

Positioning Sequence of Rod and Frame Used in Experiment 2

(From Witkin et al, 1954)

Trial Number	1	2	3	4	5	6	7	8
Frame Tilt (20°)	CC	CC	C	C	CC	CC	C	C
Rod Tilt (20°)	CC	C	C	CC	CC	C	C	CC

C - Clockwise Tilt

CC - Counter Clockwise Tilt

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