Measurement of perceived oscillation¹

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In earlier studies of perceived oscillation a comparison stimulus placed at a different distance and in a different direction from the observer than the standard stimulus was used. The usual indicators were angles relating the turning positions, produced on a comparison stimulus, to a physical frame of reference, common for standard and comparison. In three experiments where both standard and comparison were "full-cue," the effect of different spatial arrangements was studied. Difference in distance did not affect the angles describing the response, nor did monocular or binocular vision, but difference in direction from the observer and the order of giving the two turning positions, combined with the position of the comparison stimulus before responding, had significant effects. The difference between standard and comparison stimulus, which in an earlier series of experiments with artificial standard stimuli had been rather large, was not very large for most conditions in the present experiments, where a real object was used as standard stimulus. The correspondence was better, however, if another indicator, the angle describing the perceived extent of oscillation, was used. The spatial arrangements of standard and comparison stimulus affect this indicator less than the indicators relating the perceived turning positions to the axes of the physical space.

The perceptual event studied in the experiments to be described was a rod rotating back and forth in a three-dimensional space with a fixed center of rotation. This event was earlier studied by Johansson and Jansson (1967, 1968), who obtained some deviations from what was expected from a geometrical analysis of the proximal stimulation with the size of the perceived object assumed to be constant. For one stimulus an unexpected movement in depth was obtained, but for most of the stimuli the perceived movement in depth was less than predicted (about 10-15 deg). The latter deviation might be due to the extremely simple artificial stimulation studied, an animated film with a line changing only length and direction.

Also, the choice of indicators may be questioned. In the experiments mentioned a production method was used, and S indicated his percept of the standard stimulus by making a comparison stimulus appear the same in the aspect studied. There are many choices to be made between different response arrangements and also between different mathematical descriptions of the response. Similar choices concerning arrangements and description must be made also for the standard stimulus. It is a well known fact that the arrangements can be varied, but the interchangeability of descriptions seems to be less known, or is at least less utilized. It was, however, a basic idea in a series of experiments by Johansson (1950).

Response Arrangements

The indicator in mind here is a physical measure of the response given by S on the comparison stimulus. As there is no direct access to the perceived world, no criterion is available, but it seems reasonable to assume that the indicator is more valid if the comparison stimulus is presented under "full-cue" conditions, which means that the arrangements are optimal for a "correct" perception. An example of an indicator probably not valid because of not fulfilling this requirement is the first indicator used by Freeman and Pasnak (1968) in experiments related to those reported here. These authors studied the perceived

oscillation of a trapezoidal window and used as an indicator of the turning positions the slant of a rectangular surface presented under the same reduced conditions as the standard stimulus. With this indicator a perceived extent of oscillation of about 40 deg was obtained while the usual result is about 100 deg or more (Ames, 1951; Epstein, Jansson, & Johansson, 1968). It seems probable that this unexpected result depended on the slant of the comparison stimulus in relation to a frontal-parallel plane being underestimated because of the conditions not being "full-cue."

When studying the effect of different response arrangements it seems suitable to present also the standard stimulus under the "full-cue" condition. When both standard and comparison are presented in this way the corresponding physical measures of the two kinds of stimuli ought to have the same magnitude when the Ss are instructed to make the stimuli appear the same. Therefore, a bar oscillating under good lighting conditions was used as standard stimulus in these experiments.

The present study was concerned with the spatial arrangements of standard and comparison. The two kinds of stimuli cannot be perceived at the same place at the same time, a possible exception being if they are perceived as some kind of ghost objects. In Johansson and Jansson (1967, 1968) and in many similar experiments where perceived oscillation was studied (Gibson & Gibson, 1957; Epstein, Jansson, & Johansson, 1968; Freeman & Pasnak, 1968), the comparison stimulus was placed at a different distance and given a different line of sight than the standard stimulus. It might be that some of these arrangements are not suitable, as it is possible that the perceived principle axes of space may be differently related to the corresponding physical axes for these different spatial arrangements. That the perceived vertical is not stable has been shown in many contexts (for a review see Howard & Templeton, 1966).

Choice of Description

In Johansson and Jansson (1967, 1968) S produced the two turning positions of the oscillation on a comparison stimulus consisting of a real rod movable around a fixed center in all directions. Two static directions were thus chosen to represent the changing percept. An alternative is to let S produce the perceived directions continuously, as was done in a related study by Epstein, Jansson, and Johansson (1968).

The two directions may be described in different ways. Johansson and Jansson (1967, 1968) chose two angles uniquely determining each direction: ϕ being the counterclockwise deviation from the horizontal of the projection of the rod onto S's frontal plane (in the present experiments for convenience measured clockwise from the vertical), and θ being the angle between the rod and a plane frontal-parallel from S's point of view, a positive sign given to the direction away from S. (Figure 1 may be consulted for an illustration of the meaning of these definitions.) Thus, four angles in the physical space were used to describe the perceived oscillation. These indicators seem to be valid if it can be assumed that the principal axes of the perceived space have a stable relation to the corresponding axes in the physical space. If this cannot be assumed, other descriptions ought to be tried.

Problems

The experiments aimed at an answer to the following problems:

(1) Does the choice of spatial arrangements affect the ϕ and θ angles produced on the comparison stimulus?—The spatial properties studied were: difference in distance to standard and comparison stimulus and monocular vs binocular vision (Experiment 1), difference in direction from S to standard and comparison stimulus (Experiment 2), and the direction of the comparison stimulus before each pair of responses combined with the order of reproducing the two turning positions (Experiment 3).

(2) The second problem is closely related to the first: Is the relation between the corresponding angles of standard and comparison stimulus affected by these different conditions?—It may be that some conditions give such large differences between standard and comparison that they ought to be avoided. It is also of great interest to see whether the underestimation of depth obtained by Johansson and Jansson (1967, 1968) will appear in the present experiments where a different kind of stimulation was used. A result where it did not appear would indicate that the earlier result probably depended on the kind of stimulation.

(3) Are there other descriptions than the one first chosen that show less dependence on the spatial arrangements and less difference between standard and comparison stimulus?—This problem will be discussed at the end of the article.

EXPERIMENT 1

In the earlier experiments (Johansson & Jansson, 1967, 1968) the standard and comparison stimuli were located at different distances. Experiment 1 was designed to find out the possible effect of difference in distance by varying the distance between S and the standard stimulus. As binocular and monocular vision may be different, both were studied.

Method

Apparatus. The standard stimulus consisted of a cylindrical metal rod, 0.8 cm wide and oscillating on a horizontal axis, the turning positions being vertical and 50 deg from the vertical direction, respectively. The rod was sticking out of the center of a horizontal 86-cm wide circular covering surface, the latter being excavated about 1 cm deep at the center to make the rod visible down to the (imaginary) center of rotation. Visible rod length was 30 cm. One full cycle took about 8 sec, the angular speed being approximately constant. By turning the whole apparatus on a vertical axis the plane of movement could be changed in relation to S's frontal plane. The turning positions of the movements of the standard stimulus were described by the ϕ and θ angles as defined above for the comparison stimulus. They were indexed: 1 for the more vertical turning position and 2 for the less vertical. In the experiments all the ϕ_1 and θ_1 angles were zero degrees. Three placings of the standard stimulus (defined in Table 1) were used to avoid stereotyped responses.

The response device with the comparison stimulus consisted of a cylindrical rod 0.5 cm wide and 15 cm long that could be rotated around its lower end in all directions. The rod continued another 15 cm on the other side of the center of rotation, this part being used as a handle. On two protractors (the scales not visible to S) ϕ and θ were read (see Fig. 1).

Table 1

The Three Placings of the Standard Stimulus used in all the Three Experiments. γ is the Deviation of the Vertical Plane of Movement from a Frontal-Parallel Plane, ϕ_2 and θ_2 the Angles Describing the Less Vertical Turning Position.

Placing	γ	ϕ_2	θ_2
A	20	48	15
B	45	40	33
C	70	22	46

Fig. 1. The response device.

Viewing conditions. All experiments were made in a normally illuminated room. The height of S's chair was adjusted to get S's eyes in the same horizontal plane as the circular surface covering the apparatus. The distance from S's eye to the center of rotation of the standard stimulus was 152 cm and 765 cm, which corresponds to a visual angle for the rod of 11 and 2 deg, respectively, when in a vertical position.

The comparison stimulus was placed 47 cm below the horizontal plane through S's line of sight to the standard stimulus, 23 cm to the right of the vertical plane through the same line of sight, and 50 cm in front of the frontal parallel plane through S's eye. This gives a distance, from S's eye to the center of rotation of the comparison stimulus, of 72 cm, which gives the latter a visual angle of 12 deg when in a position at a right angle to S's line of sight and 10 deg when in a vertical position. Under the monocular condition one of S's eyes was covered.

Instructions. The Ss were instructed to reproduce the perceived turning positions of the standard stimulus by adjusting the comparison rod so that it seemed to be parallel to each one of them, beginning with the turning point which appeared "more vertical," although it was stressed that none of them should necessarily be vertical.

Subjects. Five undergraduate students of psychology served as Ss.

Procedure. The two distances, the monocular-binocular dichotomy, and the three placings of the standard stimulus together make 12 conditions, each one presented twice. The order was randomized, differently for each S. There was no time limit, and the standard stimulus moved continuously, until S had finished his response.

Result

The result is summarized in Table 2. Two analyses will be described here: (1) the effect of the experimental conditions on the ϕ and θ angles of the comparison stimulus, and (2) a comparison between the means of these angles and the corresponding angles of the standard stimulus.

Four analyses of variance were made, one for each one of the angles measured. A mixed model was used with Ss as random variable. At the .05 level of significance no main or interaction effects of the experimental variables (distance, monocular vs binocular vision) were found. There were significant differences in the ϕ_2 and θ_2 angles for the three different placings of the standard, but this is regarded as trivial and will not be mentioned in the following. On the other hand, the differences between Ss and many interactions between Ss and the experimental variables were significant. This indicates that there are effects, although

Table 2
The Angles ϕ and θ (deg)

Angle		ϕ_1			ϕ_2			θ_1			θ_2			
Standard stimulus placing		A	B	C	A	B	C	A	B	C	A	B	C	
Standard stimulus value		0	0	0	48	40	22	0	0	0	15	33	46	
Experiment 1														
Distance (cm)														
Monocular	152	M	-1	-1	0	50	44	35	5	3	4	18	30	45
		SD	1	1	3	5	3	11	6	7	6	8	6	7
	765	M	-1	0	-1	50	47	34	3	4	2	14	30	48
		SD	1	1	2	6	8	8	6	6	7	10	12	8
	152	M	-1	-1	-1	52	43	28	2	2	2	13	31	43
		SD	1	1	1	4	8	8	4	4	3	7	6	6
Binocular	765	M	0	1	0	48	46	32	5	5	3	17	33	45
		SD	1	1	1	5	6	8	10	9	7	11	9	7
Experiment 2														
Location of comparison stimulus														
1 (ahead)	M	-1	-1	-1	43	36	19	0	1	1	9	33	41	
	SD	1	1	1	6	5	6	2	2	3	12	8	5	
2 (to the right, low)	M	-2	-2	-2	45	39	18	0	-1	-3	14	31	40	
	SD	3	3	2	7	8	6	4	2	3	11	6	8	
3 (to the right, high)	M	1	1	1	52	43	26	-2	-3	-4	9	27	39	
	SD	2	1	1	4	7	6	3	2	3	7	7	8	
Experiment 3														
Response condition														
More vertical first	M	0	-1	-1	43	40	23	4	3	3	13	37	46	
	SD	3	2	2	9	10	4	12	7	9	13	10	7	
Less vertical first	M	0	0	-1	48	44	27	8	7	4	22	42	52	
	SD	2	2	2	9	9	8	16	7	5	16	12	8	

different for different Ss. When taken together in mean values they balance and no main effects appear. These kinds of results may be caused by subgroups of Ss reacting differently to the experimental conditions, but inspection of data shows no tendencies to grouping.

The comparison between the corresponding angles in standard and comparison stimulus showed only minor differences for the angles ϕ_1 , θ_1 , and θ_2 , usually a few degrees and never more than 5 deg. ϕ_2 , however, gave overestimation in all cases except one, especially large for placing C, the smallest standard ϕ_2 angle, where it amounts to 13 deg as a maximum.

Conclusion

The difference in distance to standard and comparison stimulus does not seem to have any important effect on the responses as there were no statistically significant main effects when distance to the standard stimulus was varied. Nor has the use of one or two eyes any effect.

The ϕ_1 , θ_1 , and θ_2 angles of the comparison stimulus were in good accordance with the corresponding standard stimulus angles. The underestimation of the θ_2 angles obtained by Johansson and Jansson (1967, 1968) was thus not obtained here. The ϕ_2 angles were overestimated, however. This might be related to the fact that the comparison stimulus occupied an asymmetrical position to the right and below the line of sight to the standard stimulus. The possible role of the location of the comparison stimulus was studied in Experiment 2.

EXPERIMENT 2

The purpose of Experiment 2 was to determine whether the difference in direction to the standard and comparison stimulus had any effect on S's responses. In the experiment the direction from S to the standard stimulus was constant and the direction to the comparison stimulus was varied.

Method

The arrangements were identical with those of Experiment 1 with the exceptions described below.

Apparatus. The rod of the standard stimulus had a length of 23 cm, and the distance from S's eye to the center of rotation was 226 cm. Three different locations of the comparison stimulus were employed, as shown in Fig. 2. In Locations 2 and 3 the whole response device was turned 90 deg to make it "point to" S in the same way as in Location 1. A headrest was used to keep S's head stationary, although allowing a 90-deg turn when the comparison stimulus was to the right. Monocular vision was used.

Instructions. When the comparison stimulus was 90 deg to the right of S, the instruction was also to "turn the perceived turning positions" 90 deg to the right. It was checked by some extreme examples that S understood the instructions.

Subjects. The Ss were five new students of psychology.

Procedure. The three locations of the comparison stimulus and the three placings of the standard stimulus were given twice and in randomized orders.

Result

A summary of the result is given in Table 2. The analysis was the same as that of Experiment 1. Significant main effects from varying the location of the comparison stimulus were found on both the angles of the more vertical position, ϕ_1 and θ_1 ($p < 0.05$). However, the mean differences of these angles were rather small. The angles in the less vertical position showed a larger difference, the means of the ϕ_2 angles being larger as the locations are ordered in the table, those of the θ_2 angles mainly being smaller. The differences between the ϕ_2 angles are statistically significant ($p < 0.01$) but not those between the θ_2 angles ($p > 0.05$) because of the larger variances. In addition to this, some of the

Fig. 2. The three locations in Experiment 2, the center of rotation of the comparison stimulus being indicated.

interactions with the S variable were significant, thus indicating that Ss react somewhat differently to the varying of the locations of the comparison.

The differences between standard and comparison stimulus values were rather small, the greatest differences being for the θ_2 angles, which usually were underestimated (up to 7 deg).

Conclusion

The difference in direction seems to have some effects on the angles measured but these effects are not very large. The agreement between standard and comparison stimulus was generally rather good. The overestimation of the ϕ_2 angles obtained in Experiment 1 was not repeated here, which indicates that the overestimation is related to the asymmetrical position of the comparison stimulus.

EXPERIMENT 3

In Experiment 3 the combined effect of the direction of the comparison stimulus before each pair of responses and the order of giving the two turning positions was studied. This was made by comparing two conditions: (1) the comparison stimulus being placed vertically before each response and S being instructed to reproduce the "more vertical" turning position first; (2) the comparison stimulus being placed horizontally in the vertical plane through the line of sight and S being instructed to reproduce the "less vertical" turning position first. In Experiments 1 and 2 only the first condition had been used.

Method

The arrangements were the same as those of Experiment 1 with the exceptions described below.

Apparatus. The center of rotation of the standard stimulus was at a distance of 380 cm from S's eye. The center of rotation of the comparison stimulus was in the vertical plane through the line of sight, in the frontal-parallel plane 50 cm from S's eye and 47 cm below the line of sight. Monocular vision was used.

Instructions. Before each pair of settings S was told with which to begin.

Subjects. Ten new undergraduate students of psychology served as Ss.

Procedure. The two response conditions and the three placements of the standard stimulus were presented twice and given in randomized orders.

Result

The result is summarized in Table 2. The statistical analysis was the same as that of the two previous experiments. Significant effects of the response conditions were found on ϕ_2 ($p < 0.01$) and θ_2 ($p < 0.05$), and nearly significant on θ_1 ($p < 0.10$). Also in this experiment the differences between Ss and a few

interactions between Ss and the experimental variables were significant. This concerns mainly the placing variable and does not disturb the interpretation of the result.

The effect of the response condition is in the direction of the starting position. The differences between standard and comparison stimulus values were generally greater when the less vertical position was reported first. The mean of the differences was about 4 deg for this condition and less than 1 deg for the other.

Conclusion

The two response conditions have effects on the ϕ_2 and θ_2 angles and tendencies to similar effects on the θ_1 angles. This indicates that the differences between the corresponding angles of the two turning positions, especially $\theta_2 - \theta_1$, may not be affected by the response conditions. The possibility of this is discussed below.

DISCUSSION

The first problem in this series of experiments was the effect of different spatial arrangements on the ϕ and θ angles of the comparison stimulus. Experiment 1 showed it to be likely that the difference in distance from S to standard and comparison did not affect the responses, nor did monocular or binocular vision. Significant effects of difference in direction from S to standard and comparison were obtained in Experiment 2, however, and the two response conditions studied in Experiment 3 differed significantly. Even if the effects were not very great in most cases, it is to be wished that that indicators would be more independent of the spatial arrangements.

The second problem was the comparison between the corresponding angles of standard and comparison. The deviations of the comparison stimulus values from the corresponding standard stimulus values for each condition of the three experiments are given in Table 3 (which also contains three angles discussed below). The result shows relatively large differences for ϕ_2 (and $\phi_2 - \phi_1$) in Experiment 1 and for the two θ angles in Experiment 3 when the less vertical position was reported first.

Table 3
The Deviation of the Comparison Stimulus Values from the Corresponding Standard Stimulus Values (deg). The Means of the Means of the Three Placings are Calculated for Each Condition. The Median and Range of the Means in the Table are given at the Bottom.

		ϕ_1	ϕ_2	θ_1	θ_2	$\phi_2 - \phi_1$	$\theta_2 - \theta_1$	δ
Experiment 1								
	Distance (cm)							
Monocular	152	-1	6	4	0	7	-4	2
	765	0	7	3	-1	7	-3	3
Binocular	152	-1	4	2	-2	5	-4	1
	765	0	5	5	1	5	-4	1
Experiment 2								
Location of comparison stimulus								
1 (ahead)		-1	-5	1	-2	-4	-4	-4
2 (to the right, low)		-2	-3	-1	-3	-2	-1	-1
3 (to the right, high)		1	3	-3	-6	2	-3	1
Experiment 3								
Response condition								
More vertical first		-1	2	3	1	-1	-2	-2
Less vertical first		0	2	6	8	3	2	2
Median		-1	3	3	-1	3	-3	1
Range		2	12	9	11	11	6	7

but in most cases the mean differences were only a few degrees. From this result the conclusion may be drawn that a location of the comparison stimulus obliquely in relation to the standard, as in Experiment 1, ought to be avoided. As can be seen in Table 2 the difference in ϕ_2 angles was especially large for small standard stimulus angles. The rather large difference for the θ angles obtained in the condition with the less vertical reported first in Experiment 3 is probably related to the general orientation of the angles in these experiments. Most of them are nearer the vertical than the horizontal (cf. Table 1). For some angles a mean of the two response conditions gives a smaller deviation, and this may be preferred at least in experiments with a large variation of angles.

The deviation of the comparison from the standard in these experiments is smaller than the deviation from the predicted θ_2 angles in Johansson and Jansson (1967, 1968). This makes it probable that the result, in this respect, of the earlier experiments depended on the kind of stimulation and not on the response arrangement.

The relatively large deviations of the comparison stimulus values from the standard stimulus values for some angles motivated a search for alternative indicators (Problem 3). The covariation of the θ angles in Experiment 3 indicated the possibility of relative angles being less affected by the spatial arrangements. The two differences $\theta_2 - \theta_1$ and $\phi_2 - \phi_1$ were calculated for each response and analyzed in the same way as the first group of indicators (see Table 4). The analysis of variance gave no significant main or interaction effect of the variables studied in Experiments 1-3 for $\theta_2 - \theta_1$ but $\phi_2 - \phi_1$ was, as was ϕ_2 , significantly affected by the difference in direction in Experiment 2 ($p < 0.05$), and also of the dichotomy monocular-binocular in Experiment 1 ($p < 0.05$). The values of the difference $\phi_2 - \phi_1$ are very similar to those of ϕ_2 , because of the stability of ϕ_1 . Significant interactions with Ss occur about as

often as for the pure ϕ and θ angles and should be interpreted in a similar way.

The comparison between standard and comparison showed that nearly all the values for $\theta_2 - \theta_1$ are smaller than the corresponding standard stimulus values (see Table 3). In contrast to this $\phi_2 - \phi_1$ is generally larger than the standard stimulus value. Therefore, a new angle was calculated for each response and given the same analysis as the angles above. This angle, called δ , was the amplitude of the rotation, i.e., the angle between the turning positions themselves, calculated by the formula

$$\cos \delta = \cos \theta_1 \cos \theta_2 \cos (\phi_2 - \phi_1) + \sin \theta_1 \sin \theta_2.$$

The data for δ are also given in Table 4. Except for interactions with Ss the analysis of variance gave one significant effect ($p < 0.05$) for this angle, namely, of the location of the comparison stimulus in Experiment 2. There was no systematic difference between standard and comparison; about the same amount of positive and negative deviations were obtained.

Three alternative descriptions of the partial oscillatory motion are discussed here. The first alternative is the two pairs of ϕ and θ angles, the second the two differences $\theta_2 - \theta_1$ and $\phi_2 - \phi_1$, and the third the δ angle. These alternatives will be compared in several ways.

The analyses of variance gave several significant differences for the first alternative. In the second alternative $\phi_2 - \phi_1$ was significantly different in some cases, but there was no significant difference for $\theta_2 - \theta_1$ (observe, however, the larger variances). δ obtained one significant difference.

The difference between standard and comparison for each indicator may roughly be compared by calculating the median and range of the deviations in Table 3 (given at the bottom of the table). The indicators had rather different ranges of the means. ϕ_1

Table 4
The Angles $\phi_2 - \phi_1$, and $\theta_2 - \theta_1$ and δ (deg)

Angle		$\phi_2 - \phi_1$			$\theta_2 - \theta_1$			δ		
Standard stimulus placing		A	B	C	A	B	C	A	B	C
Standard stimulus value		48	40	22	15	33	46	50	50	50
Experiment 1										
Distance (cm)										
Monocular	152	M	51	45	37	13	27	42	51	53
		SD	5	4	10	8	9	8	5	8
	765	M	51	47	35	12	26	45	52	56
		SD	6	8	8	10	10	11	6	7
	152	M	52	44	29	11	29	41	53	49
		SD	3	9	8	6	7	6	4	5
Binocular	765	M	48	46	32	12	28	42	49	51
		SD	4	7	8	12	12	9	6	9
Experiment 2										
Location of comparison stimulus										
1 (ahead, low)	M	51	42	25	9	33	40	46	48	44
	SD	5	7	6	12	7	7	5	5	6
2 (to the right, low)	M	46	40	20	14	31	43	49	50	47
	SD	7	8	7	13	7	8	7	5	7
3 (to the right, high)	M	43	36	19	11	30	43	52	51	49
	SD	5	5	6	8	6	7	5	6	6
Experiment 3										
Response condition										
More vertical first	M	43	41	25	9	34	43	44	51	48
	SD	10	11	4	12	11	11	11	13	10
Less vertical first	M	48	44	28	14	35	48	50	52	54
	SD	9	9	8	19	11	9	13	9	9

was very insensitive to the experimental conditions but ϕ_2 and θ_2 were rather sensitive. The second alternative gave a smaller range for $\theta_2 - \theta_1$ than the ranges for the separate angles, but the range for $\phi_2 - \phi_1$ was nearly the same as that for ϕ_2 . The third alternative had a median and a range in between those of the second alternative.

Taken together the comparisons made seem to favor the third alternative. A better correspondence between "full-cue" standard and comparison stimulus is obtained when the indicator δ is used. The perceived extent of oscillation seems to have a more stable relation to the corresponding physical indicators than the perceived turning positions. This may be due to the indicators for the latter, the ϕ and θ angles, being influenced not only by the perceived extent but also by the general spatial framework. It may be noted, however, that the angles describing the relation between the turning positions ($\phi_2 - \phi_1$, $\theta_2 - \theta_1$, and δ) do not give any information about the general orientation of the extent in relation to some spatial framework, and thus do not uniquely determine the response. Should the orientation of these angles be of interest some further description must be added.

The use of the δ angle to describe the responses in the study by Johansson and Jansson (1967, 1968) reduces one of the deviations from the predictions mentioned in the beginning of this article. An unexpected movement in depth of about 10-15 deg, measured in θ angles, is reduced to about 4 deg if, instead, a δ angle is calculated (from the means of the ϕ and θ angles obtained). The other deviation with less depth than predicted was not very much reduced, however, and it seems reasonable to ascribe this deviation to the kind of stimulation

used, as discussed above. A next step in this series of studies would be to do experiments studying the differences between the artificial standard stimulus used by Johansson and Jansson (1967, 1968) and the "full-cue" stimulus used here.

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NOTES

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