Contrast and Assimilation in Illusions of Extent

by

© Alexander E. Wilson

A thesis submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy in the Department of Psychology in the Faculty of Graduate Studies of the University of Manitoba.

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Abstract

The major aim of this research was to evaluate the role of contextual extent and spatial separation on contrast and assimilation in illusions of extent. Contextual extent and spatial separation were altered in the parallel lines configuration. Displays consisted of a test line, a response line, and contextual lines. Contextual extent was defined as the length of the contextual line and spatial separation was defined as the perpendicular distance between test and contextual lines. The contextual line was placed either between test and response lines (the below position) or on the side of the test line opposite to the response line (the above position).

In Experiment I the results confirmed previous findings which showed decreased degree of assimilation illusion with increased spatial separation, an inverted U-shaped function between degree of illusion and contextual extent, and larger illusions with below positions of context than with above positions. One unexpected finding was the observation of contrast with short contextual lines. From various theoretical perspectives, it had been predicted that contrast would occur with either long contextual lines and or large spatial separations.

Experiments II and III were conducted to assess the reliability of the initial findings. Experiment II confirmed that contrast occurred with short contextual extents and that degree of contrast was inversely related to spatial separation. In Experiment III, as in Experiment I, no contrast occurred with long contextual lines.

In the next study, a forced-choice procedure was used to collect responses to displays with the shortest contextual extent used in the

previous studies. Subjects indicated if either the test or the response line appeared longer. Again contrast occurred and its magnitude decreased with increased spatial separation.

In Experiment V, two contextual lines surrounded the test line. They were positioned on opposite sides of the test line and were an equal distance from the line. The results were similar to those of Experiment I. However, there was less contrast with the shortest contextual extent and it was inferred that contrast might occur, for small separations, with contextual lines longer than the ones used.

Acknowledgments

It is my pleasure to express my gratitude to Dr. A.W. Pressey. In my years as a graduate student, he has taught and guided me in all of my endeavours. Professor Pressey, thank-you for your help and kindness.

I would also wish to express my appreciation to the other members of my committee. Professor Brewster, in the department of Statistics, has served faithfully on my committe since its inception. His suggestions and comments have proven very helpful. Professors R.W. Tait and S. Holborn made very valuable contributions. Dr. Holborn made many suggestions which improved the clarity and style of my writing. Dr. Tait was invaluable for advice in programming and research design.

I must express a special thank-you to my wife, Johanne, and my children, Eric, Alexandra, and Marianne. They have supported me faithfully in this endeavor.

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Introduction

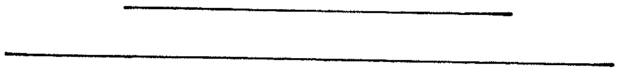
If we look at Figure 1 it will be noticed that line _b_ appears shorter than line _a_ but longer than line _c_. Measurement with a ruler reveals, however, that each line is of equal physical length. The simple configurations displayed in Figure 1 demonstrate the essence of illusions; namely, that context alters appearance.

Assimilation and contrast, one traditional classification of illusions (Woodworth & Schlosberg, 1938), corresponds to the direction of the effect induced by a context. For illusions involving assimilation, such as the ones shown in Figure 1, physical differences between test and contextual extents are reduced perceptually. For those involving contrast, physical differences are enhanced perceptually. If, in Figure 1, the length of line _a_ appeared shorter than the length of line _b_, then the illusion would be termed one of contrast since the difference between the lengths of line _a_ and the contextual line would have been increased.

However, it may be unnecessary to use the categorization of Woodworth and Schlosberg (1938) since, from one point of view, it can be argued that configurations induce both contrast and assimilation. This point of view, has been articulated most explicitly by Pressey (1967), and it states that distances between contours parallel to the test extent form the effective context. From this assumption the effects induced by the parallel lines configurations shown in Figure 1 are soley ones of assimilation. This assumption is not only applicable to simple displays

Figure 1: Lines *a*, *b*, and *c* do not appear to be of equal length, although they are of equal physical extent.

a



b

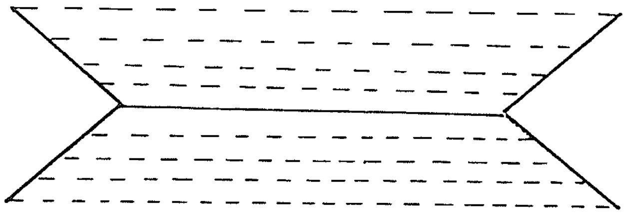
c

such as the parallel lines configuration but also to more complex displays such as the Muller-Lyer. In the Muller-Lyer, for instance, the argument is made that the effective context is formed by implicit distances found between the pair of opposing wings. From this assumption the illusions depicted in Figure 2 can be considered to be ones of assimilation, since when contextual distances are longer than the test extent, the illusion is one of expansion; when distances are shorter than the test extent, the illusion is one of shrinkage. This assumption also changes the classification of some illusions, such as the Baldwin, from one of contrast to one of assimilation (Pressey & Wilson, 1980). Typically, it is thought that the extent of the individual boxes in the Baldwin configuration (Figure 3a) form the effective context. Since, when the boxes are shorter than the test extent, the test line appears elongated, it is assumed that the illusion is one of contrast (*e.g.*, Woodworth & Schlosberg, 1938). However, if the context which induces the illusion is formed between the edges of pair of boxes, as is shown in Figure 3b, then the illusion is one of assimilation and not one of contrast.

Illusion as a function of contextual extent

When contextual extent is longer than test extent, illusions are mainly ones of assimilation (Brigell, Uhlarik, & Goldhorn, 1977). However, it can also be argued that contrast is systematically related to contextual extent; when contextual extent is much longer than test extent contrast occurs (See Obonai, 1954, who made a similar argument). Therefore, when there is little difference between contextual and test extents, assimilation occurs, but when there is great difference, contrast results. (See Appendix A for a more complete discussion on the

Figure 2: The two, solid horizontal lines are altered in apparent length by the contextual extents (the dashed lines) formed between the pair of opposing fins.



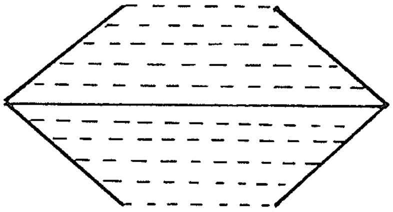
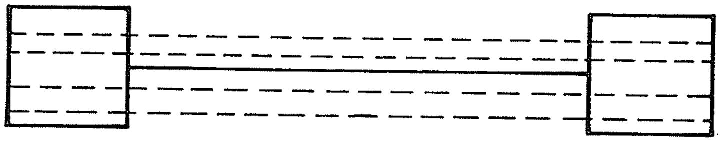


Figure 3: In the Baldwin display, when the boxes are small the test line appears elongated (A). In (B) the hypothetical contextual lines, which are represented by the dashed lines, are shown.

A

B



effects of contextual length and other variables which affect degree of illusion.)

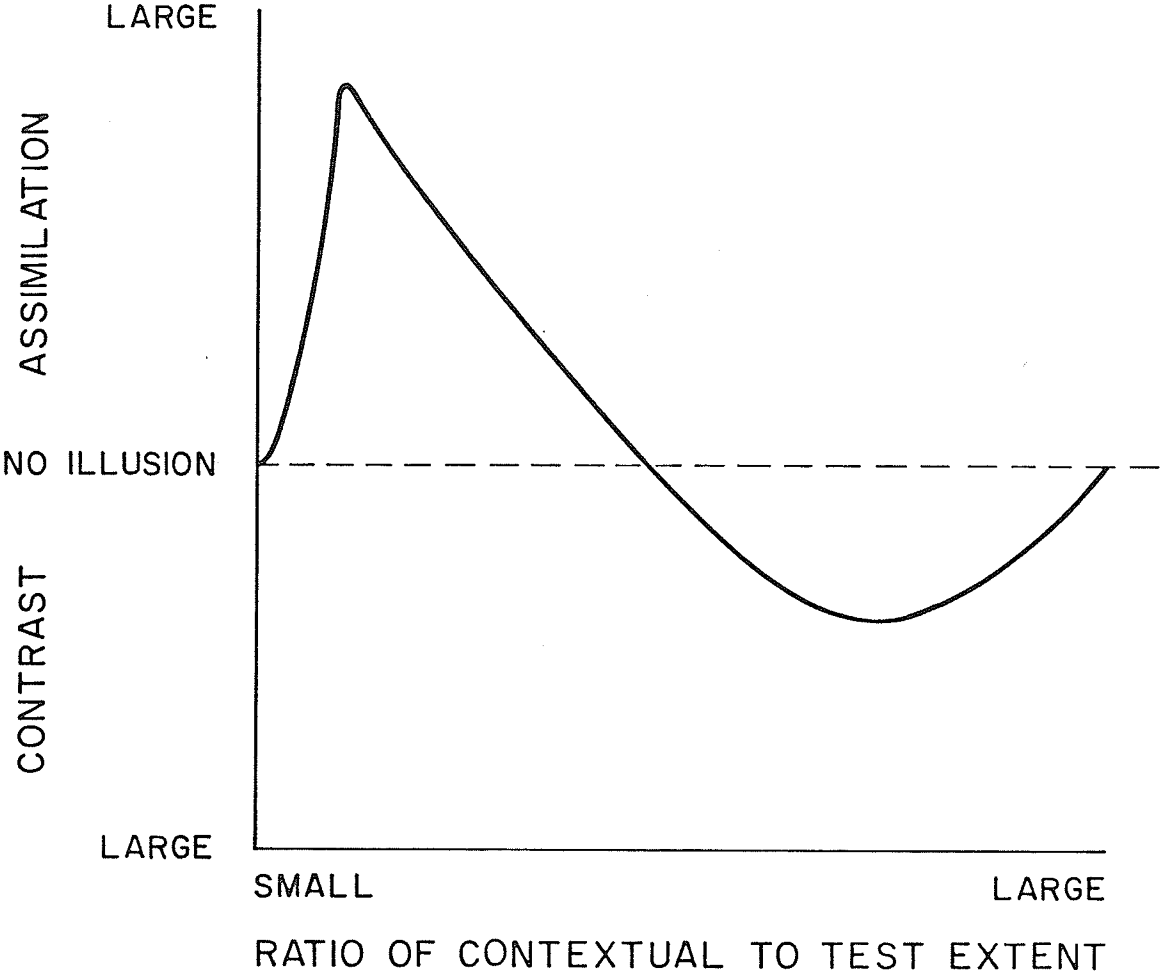
A hypothetical function is presented in Figure 4 which depicts degree of illusion as a function of contextual extent. For contextual extents longer than the test line, it shows that when contextual extent initially increases, degree of assimilation increases and then decreases. Then with further increases in contextual length, the illusion changes from one of assimilation to one of contrast. This hypothetical function coincides closely with results obtained with Baldwin (Pressey & Wilson, 1980), Delboeuf (Keats, 1964), Muller-Lyer (Restle & Decker, 1977), and Titchener circles (Girgus, Coren, & Agdern, 1972) configurations.

However, findings from two recent studies do not confirm the contrast portion of the function. Neither Brigell et al, (1977) with Muller-Lyer, divided lines, and Baldwin configurations, nor Clavadetscher and Anderson (1977) with Baldwin displays obtained contrast. Thus, their studies challenge the idea that contrast is systematically related to contextual extent. One of the aims of the present research was to resolve the issue of the relationship between contextual extent and contrast.

Spatial separation

A second aim of the present research was to assess the effect of spatial separation (the perpendicular distance) between test and contextual extents on contrast. It is well known that spatial separation affects degree of assimilation illusion (Girgus et. al, 1972; Pressey & Murray, 1976) but the role it plays in the occurrence of contrast is unknown. In Delboeuf (Keats, 1964; Ikeda & Obonai, 1955) and Titchener

Figure 4: A hypothesized relationship between ratio of contextual to text extent and type of illusion.


LARGE
ASSIMILATION
NO ILLUSION
CONTRAST
LARGE
SMALL
LARGE
RATIO OF CONTEXTUAL TO TEST EXTENT

circles (Girgus, et al, 1972) displays, where contrast seems to be most firmly established, there is a clear separation between test and contextual components. Therefore, spatial separation may be responsible for the occurrence of contrast induced by those displays. However, from the point of view expressed above (Pressey, 1967), it can be argued that contextual extent (for example, the diameter of the contextual circle in the Delboeuf display) covaries with separation (the distance between test and contextual circles). Therefore, it is plausible that contextual extent and not separation is responsible for inducing contrast in these displays.

Theoretical Considerations

Research designed to investigate the separate and interactive effects of contextual extent and separation has considerable theoretical merit. In several theories of illusions, especially those which include quantitative models, contextual extent and separation play major roles in explanations. (Chapter 3 in Appendix A contains a review of theories of illusions.) Therefore, evaluation of competing theories of illusions can be accomplished through investigation of the separate and interactive effects of contextual extent and spatial separation. An additional aim of this study was, therefore, to evaluate theories on the basis of the independent and interactive effects of these two variables.

Assimilation is easily explained if perceived test extent is a result of some process that averages test and contextual extents since the perceived length of the test line will be altered towards the length of the context. When that occurs, the physical difference between test and contextual lengths is perceptually reduced. Furthermore, results of this hypothetical process correspond closely with functional relationships between degree of illusion and alteration of several configurational components within Muller-Lyer displays. For example, Pressey (1972) found that degree of illusion covaried linearly with changes in contextual extent, when contextual extent was altered by changes in angle between fins.

Although recent theoretical reviews (Coren & Girgus, 1978; Robinson, 1972) recognize an averaging process to be a powerful explanatory tool, it is by itself insufficient to explain some of the findings involving assimilation. Consider, for example, the assimilation portion of the hypothetical function displayed earlier. It shows a nonmonotonic relationship between degree of illusion and contextual extent and it is a reliable function (Brigell et al, 1977); however, a simple averaging explanation, would predict a linear relationship between degree of illusion and contextual extent as contextual extent increases in length. Because of contrary nonmonotonic findings, theories which incorporate an averaging process maintain that perceived test extent is modulated by other factors; i.e., it is a weighted average of test and contextual extents.

To explain contrast, several options are available. One option uses as its basic assumption a principle which maintains that all physical differences are subjectively enhanced. This is the basis of adaptation-level theory. Proponents of this theory argue that contrast occurs because test extents are judged in relation to a weighted average of all extents in the field (Restle & Merryman, 1968; Restle & Decker, 1977). Another option relates some psychophysical variable, such as spatial separation, to the occurrence of assimilation and contrast and proposes a known physiological process, for example lateral inhibition (Brigner,

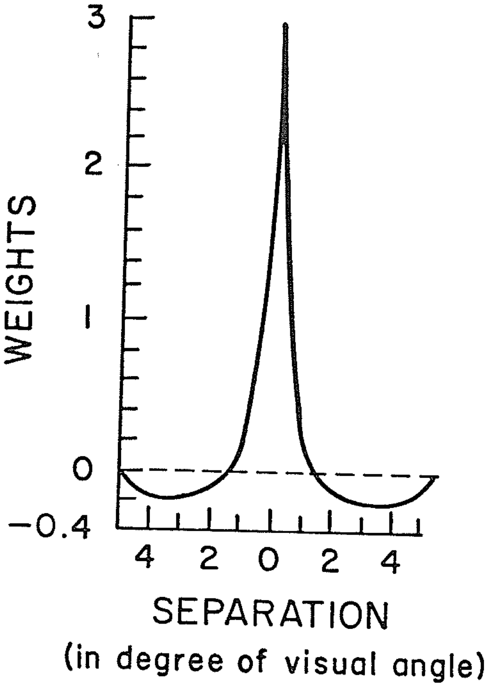
1977) or a logical construct, such as interactive fields, (Pressey & Wilson, 1980), to account for the relationship.

Framing theory. Brigell et al. (1977) support the idea, which they attribute to Kunnapas (1955), that the length of a configuration provides a frame in which the test extent is judged and that it is this frame which alters the apparent length of the test line. They argue that the critical feature of a configuration which determines the degree of illusion is the ratio of configurational (contextual) to test extents. Furthermore, these authors have incorporated recent neurological evidence to buttress their theoretical model of how a frame could alter apparent length.

They explain the effects of a frame on the basis of channels in the visual system that are sensitive to length. It is argued that channels respond to a limited range of extents and that as a length diverges from the extent producing the optimal response, level of responding decreases. When a contextual length stimulates channels sensitive to the test extent, the level of responding of those channels is an average of responses produced separately to test and contextual lengths. Since perceived test extent is postulated to correspond directly to the extents to which channels are sensitive and to their level of responding, introduction of contextual extents that stimulate channels sensitive to the test extent alters the perceived length of the test extent. The perceived length is altered towards the length of the contextual extent because the level of responding of channels is an average of the degree of responding induced by both test and contextual extents. When contextual extents are longer than the test length, degree of illusion initially increases and then decreases until contextual lengths no longer share the same channels excited by the test line. When test and contextual lengths no longer share the same channels, an illusion does not occur. This pattern of change in degree of illusion occurs because, when contextual extents become longer than the test extent, the average level of responding of channels sensitive to the test extent, but which are maximally sensitive to longer lengths, respond at a greater level then when stimulated soley by the test extent. Thus, when contextual extents initially become longer than the test extent, degree of illusion initially increases. With further increases in contextual extent, the level of responding of those channels increases, reaches a peak, decreases, and then, when test and contextual extents no longer share the same channels, returns to the level of responding induced only by the test line. Since separation is not included in the theory, predictions concerning the effects of separation per se cannot be made. However, if it is assumed that separation does not alter the interaction between the distribution of responses to test and contextual extents, then it would be predicted that the contextual length producing peak illusion and the range of lengths producing illusion would be identical for displays with different degrees of separation.

Lateral inhibition theory. Brigner (1977) also proposes an explanation based upon a weighted average of responses produced by channels sensitive to length; however, the weighting is given by the degree of lateral inhibition among channels sensitive to length. In Figure 5 it is seen that the weighting function is related to degree of separation between test and contextual extents. When they are in close spatial proximity assimilation occurs, but as separation increases assimilation decreases and contrast results. Finally, with larger separations no

Figure 5: The weighting function proposed by Brigner (1977). Positive values produce assimilation and negative values produce contrast.


3
2
1
0
−0.4
WEIGHTS
4
2
0
2
4
SEPARATION
(in degree of visual angle)

interaction occurs between the lines and hence no illusion is induced.

The weighting function described by Brigner is derived empirically, not theoretically. He argues that, at the present time, there is insufficient knowledge about the properties of the the visual system to derive theoretical models based upon neurophysiological processes. Therefore, he suggests that to develop mathematical models, one must use psychophysical methods to discover functional relations and then incorporate the functional relations into mathematical models.

In Brigner′s mathematical model, perceived extent is a function of test and contextual extents and the weights assigned to the extents. To predict perceived test length, each extent is multiplied by its assigned weight and then the sum of the products of each extent multiplied by its weight is divided by the sum of the weights. Weights are assigned according to the degree of spatial separation between test and contextual extents. For example, in the parallel line configuration, the test extent would be assigned the weight related to a spatial separation equal to 0 degrees of visual angle and the contextual extent would be assigned the weight which corresponds to its degree of separation from the test extent. The predicted (perceived) length is then calulated by summming the products of each extent multiplied by its corresponding weight and then dividing the sum of the products by the sum of the weights.

The following predictions are made by lateral inhibition theory. First, it is predicted that if separation increases, then magnitude of assimilation illusion will decrease and that with further increases in separation the illusion of assimilation will change to one of contrast and eventually to no illusion. The change in illusion will follow the weighting function. Second, it is predicted that if contextual extent increases, then degree of illusion will increase. Furthermore, since the degree of illusion depends upon the weighting function it is predicted that the rate of increase in illusion will vary as a function of separation.

Adaptation-level theory. From the perspective of adaptation-level theory (Helson, 1964) it is argued that the judged extent of a test line is directly related to the length of the test line but inversely related to adaptation-level (Restle & Merryman, 1968). Adaptation-level is a pooled norm formed from a weighted average of test length, contextual extent, and past experience. An early application of the theory (Restle & Merryman, 1968) explains only simple contrast effects; however, in more recent versions (Restle, 1978; Restle & Decker, 1977), it explains assimilation effects in illusions of expansion and the nonmonotonic function between degree of illusion and contextual length.

In this recent formulation it is argued that adaptation-level is formed by a weighted average of length of contextual stimuli and a field. By a field it is meant the average of background lengths. These lengths could include such items as length or height of a room, the extents of the equipment containing the displays, etc. Furthermore, it is maintained that the weight assigned to the context varies as a function of its length. When the context is short, it has little influence on altering adaptation-level but as it becomes longer its influence increases.

According to adaptation-level theory, illusions occur when the test extent is judged in relation to an adaptation-level that is different from the one which occurs when the test line is viewed without a context. When the context is shorter than the length of the field, adaptation-level is lowered and the test line appears elongated. However, when a line longer than the length of the field forms the context, adaptation-level is raised and the test line decreases in perceived length. When contextual length varies between the cases of zero length and equal in length to the extent of the field, its influence on altering adaptation-level varies. When it is very short, it has very little influence on adaptation-level. Therefore, a small illusion will occur. When it is the same length as the field, its influence on the formation of adaptation-level is maximized (Restle, 1978), but since it is the same length as the field, adaptation-level is of the same magnitude as when a context is not present. Thus when the context is as long as the extent of the field no illusion will result. Between these two conditions, contextual extents will have a greater effect on altering adaptation-level, from the level found when a context is not present since they will have a greater weight then when they are very short and since their difference in length from the extent of the field will be greater then when they are equal in length to the length of the field. That is, the theory states that there is a nonmonotonic relation between length of context and effect on adaptation-level. Therefore, since lengths longer than very short lengths and lengths shorter than the extent of the field have greater influence on altering adaptations-level larger illusions will occur. Furthermore, to simplify the theoretical relation, it is also assumed, that one of the lengths falling between the two extreme conditions will have the greatest effect on altering adaptation-level (Restle & Decker, 1977). Therefore, as contextual length increases from a very short extent to an extent as long as the length of the field, magnitude of illusion will initially increase and then decrease.

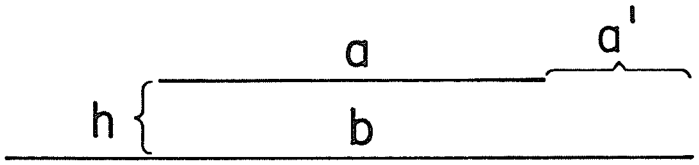
If contextual extents, which are slightly longer than the length of the test line, represent very short lines, then the following prediction can be made from adaptation-level theory. If contextual extents increase in length, then the apparent length of the test line will initially increase, then decrease, and when the adaptation-level becomes greater than the one found without a context, appear shorter than its physical length. This prediction also assumes that when the contextual lines are very long that they will be longer than the length of the field, otherwise contrast would not be predicted to occur.

Predictions on the effects of separation depend upon the assumptions made. If the distance between test and contextual extents does not enter into the formation of the adaptation-level, which is unlikely if past research is considered (Restle & Merryman, 1969), then alteration in separation will not affect degree of illusion. On the other hand, if separation does affect adaptation-level, a question is raised concerning how it enters into the formation of adaptation-level. On the basis of past theory (Restle & Merryman, 1969), the weight assigned to each level of separation would be constant; however, this is considered to be an empirical question (Restle, 1978). If the weight assigned to each magnitude of separation is a constant, then small separations will change adaptation-level more than large separations since the difference in length between a short separation and the field would be greater than the difference in length between a large separation and the field. Therefore, it is predicted that if magnitude of separation increases then the apparent length of the test line would decrease. If the test line appears to decrease in length then either the degree of assimilation illusion will decrease or the degree of contrast illusion will increase.

From the last assumption made above there is one additional prediction to be made. This prediction concerns the contextual length where the transition from apparent expansion to apparent shrinkage of the test line occurs. Consider the following argument. A test line viewed by itself has the adaptation-level formed only by the field. Presenting a contextual line shorter than the field lowers the adaptation-level and hence apparent expansion of the test line occurs. As the contextual line increases in length, the adaptation-level approaches the one formed only by the field. When the adaptation-level reaches the one formed only by the field there is a transition from apparent expansion to apparent shrinkage of the test line. Now consider an instance in which there are two illusion configurations, one with a short separation and the other with a large separation. The one with the short separation will lower adaptation-level more than the one with a large separation. Therefore, to reach the adaptation-level formed only by the field, a longer contextual line is required for the display with the short separation than for the one with the long separation. Therefore, it is predicted that if separation increases, then a shorter contextual line would be required to produce apparent shrinkage of the test line.

Piagetian theory. Piaget (1969) argues that illusions result from perceptual accentuation of differences in length between physical and/or subjective lengths found within configurations. For Piaget there are three lengths of importance in the parallel lines display. These lengths, which are labelled in Figure 6, are the shaft (a), contextual

Figure 6: Piaget considers test extent, *a*, contextual length, *b*, and the difference in extent between *a* and *b*, *a'*, to be important in altering apparent length of line *a*. Spatial separation between *a* and *b*, *h*, is used in his formula, which predicts magnitude of illusion.


a
a'
h
b

length (b), and one-half the difference in length between shaft and and contextual lines (a'). In his explanation he suggests that *a* and *2a′* are perceived as equal in length to *b*; *i.e.*, $a+2a'=b$. He also suggests that the length of the contextual line is compared with the difference in length between a and b, that is b is compared with $2a'$. Since *2a′* is shorter than *b*, *2a′* appears to be diminished in length; but since $a+2a'=b$, *a* increases in apparent length to maintain the equation, $a+2a'=b$.

Piaget also incorporates separation into his theory. On the basis of empirical research he argues that as separation increases, magnitude of illusion decreases; that is, he postulates an inverse relation between magnitude of illusion and degree of separation. To predict degree of illusion Piaget uses the formula $p=(b-2a')2a'/b^2h$; where *p* refers to magnitude of illusion, *h* is separation between test and contextual lines, and *b* and *a′* are as defined above.

This formula was developed by Piaget on the basis of trial and error. That is, Piaget did not derive the formula from a theoretical basis, but rather arrived at it through comparison of predictions from different formulas with empirical findings. He chose the formula which best matched the trends of data.

Substitution of values into the formula reveal the following predictions. For contextual extents longer than the test extent, it is predicted that if contextual length increases then magnitude of illusion would increase until the contexual length becomes twice as long as the test extent, then degree of illusion would decrease; however, it is not predicted that the test line would appear shorter than its physical length. Finally, it is also predicted that if separation increases then magnitude of illusion would decrease.

Assimilation theory. Like Brigner (1977) and like Brigell et al (1977), Pressey (1967; 1971; Pressey & Murray, 1976) argues that perceived extent of a test line is a weighted average of contextual and test extent. Unlike the other theorists, Pressey does not use neurological explanations. Furthermore, the theory can be distinguished from the other theories because more factors are postulated to affect the "averaging process". There are three factors which enter into the weighting; namely, range (the difference in length) between test and contextual extents, separation, and attention. From the range factor it is argued that degree of illusion increases with an increase in the difference between test and contextual extents (Pressey, 1972).

The effects of separation are explained by the construct of an interactive field (Pressey & Murray, 1976). It is held that as separation increases, degree of illusion decreases. To incorporate an interactive field within a quantitative model used to predict degree of illusion, it is operationally defined as a circular region with its center located (more or less arbitrarily) at one of the ends of the test line. Furthermore, it is postulated that the effectiveness of a contextual line, in altering apparent test extent, decreases when distance between the endpoint of a test line and the endpoint of a contextual line increases.

Initially, interactive fields were used to explain decreases in magnitude of illusion, for illusions of assimilation, when separation between test and contextual lines increased (Pressey & Murray, 1976). Then, to explain contrast effects, the properties associated with the construct of an interactive field were modified (Pressey & Wilson, 1980). It is now argued, as shown in Figure 7 , that the field is divided into two circular regions, an inner one where assimilation is produced and an outer one where contrast is generated. Thus assimilation is produced with short distances and contrast is generated with long distances between the endpoints of test and contextual extents. Therefore, like lateral inhibition theory (Brigner, 1977), the theory maintains that contrast can occur by altering separation, but unlike lateral inhibition theory, it also suggests that contrast can result from altering contextual extent, since through manipulation of either variable the endpoints of contextual extents can fall within the contrast portion of the interactive field.

The role of attention is included in the concept of attentive fields. It is postulated that the closer a context is to the center of attention, the greater the influence of the context in altering the apparent length of the test line. The center of the field is operationally defined as the midpoint between the most extreme elements to be judged. To find the center of the field, one must first locate the most extreme elements to be used in performing the task and then calculate the location of the midpoint. For example, if subjects are required to compare the lengths of lines a and b in Figure 8, the endpoints of each line must be viewed by the subject to perform the task. These are the most extreme elements. Then one must find the location of the midpoint among these endpoints. From elementary geometry it is known that the midpoint lies at the point of intersection of lines which join the opposite ends of the two lines to be judged (see Figure 8). It is at the point of intersection that the center of the attentive field is located. The location of an attentive field is

Figure 7: An example of an interactive field. It is located at the endpoints of the test line.

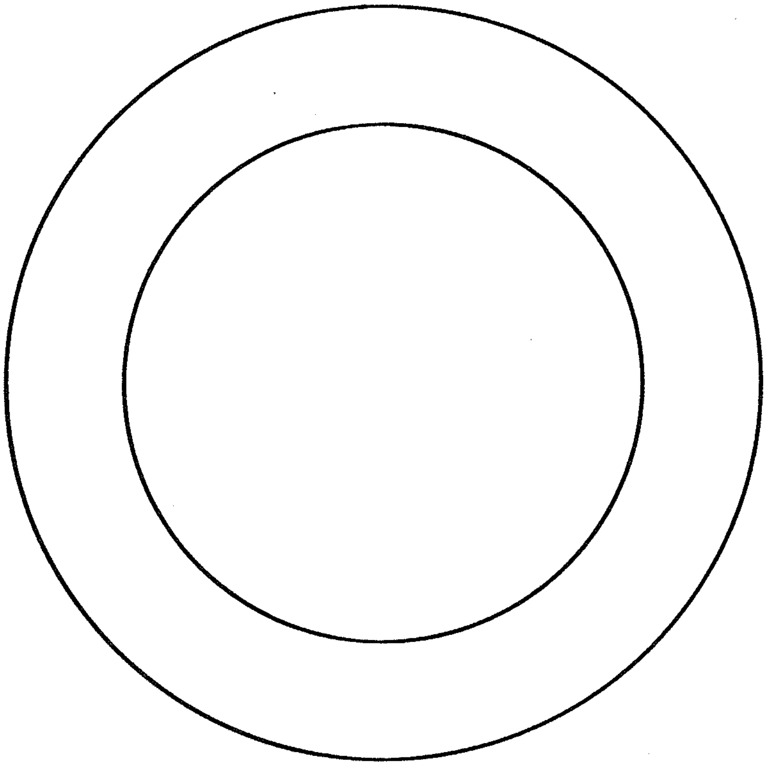
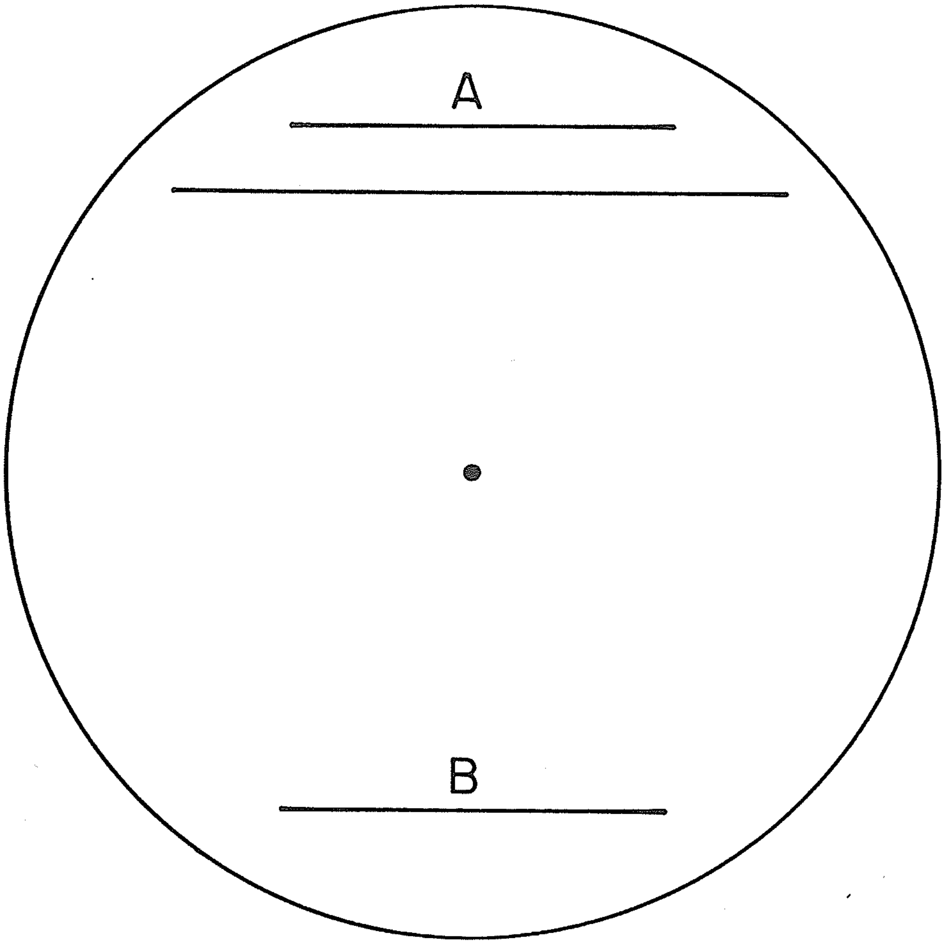


Figure 8: The circle represents an attentive field.


A
B

depicted in the parallel lines configuration shown in Figure 8. When a contextual line is placed between the test and response line, it will be closer to the center of the field than a line placed on the opposite side of the test line. Therefore, it will have greater influence in altering the test line then when it is on the opposite side. Because of this, different predictions are generated when position of the contextual line is altered. Therefore, position was also varied in the present research. It should be noted that predictions regarding the effects of this variable cannot be generated from the other theories without the addition of relevant assumptions.

To produce predictions from assimilation theory, values can be substituted into a mathematical formula provided by Pressey and Murray (1976). Since contrast has yet to be incorporated into the formula, predictions concerning the degree of assimilation illusion are the only ones which can be generated. From Figure 9, where the results of substitution of numerical values in the formula are depicted, the following predictions can be made. First, if position of the contextual line is altered, then magnitude of illusion will be greater when the contextual line is positioned below the test line (that is, when it lies between the test and response lines), then when it is placed above the test line. Second, if the contextual line is increased in length then magnitude of illusion will initially increase and then decrease. Third, it is predicted that if separation increases then magnitude of assimilation illusion will decrease.

Summary of predictions. In Table 1, predictions made from each of the theories are summarized. It can be noted that framing theory and Piagetian theory predict only assimilation.

Figure 9: Predictions made by assimilation theory.

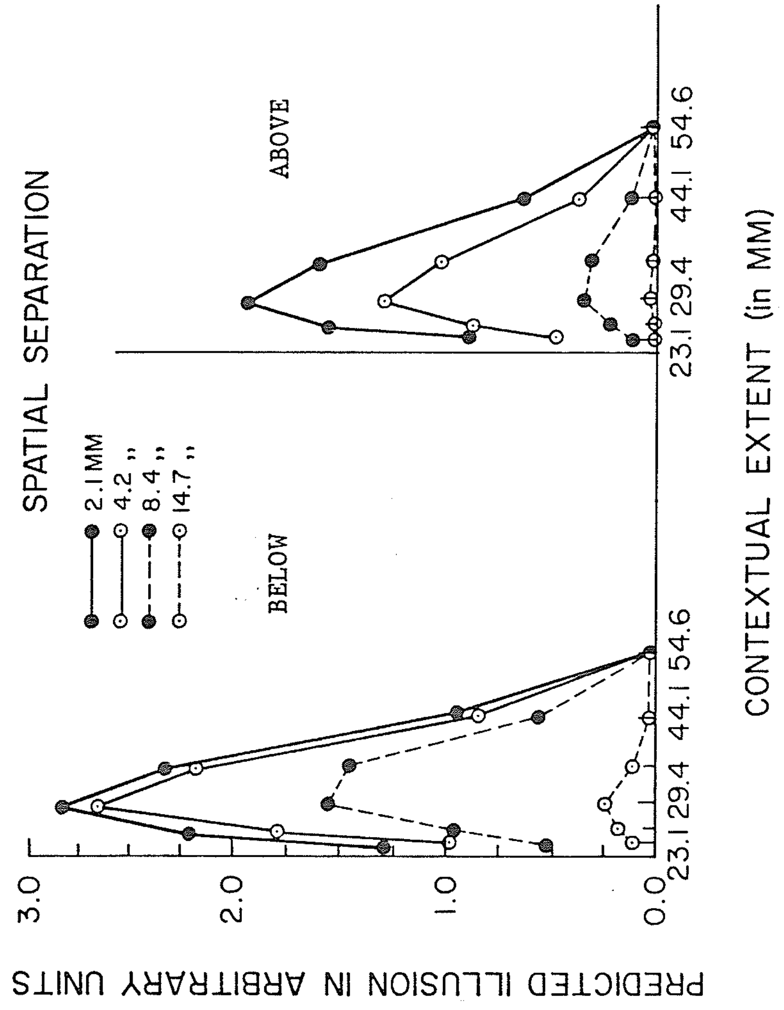

SPATIAL SEPARATION
2.1 MM
4.2 ,,
8.4 ,,
14.7 ,,
BELOW
ABOVE
PREDICTED ILLUSION IN ARBITRARY UNITS
3.0
2.0
1.0
0.0
23.1
29.4
44.1
54.6
23.1
29.4
44.1
54.6
CONTEXTUAL EXTENT (in MM)

TABLE 1: Predictions Made by the Theories.

TABLE 1

Predictions Made by the Theories

Theory	A.	C.	Variables(s) Producing Contrast	Effects of Increasing Contextual Length	Effects of Increasing Separation	Change in Position
			Predictions			
Framing Theory	Yes	No	NA	Increase and decrease in A.	N.P.	N.P.
Lateral Inhibition Theory	Yes	Yes	Separation.	Linear change in illusion.	Decrease A. Increase C.	N.P.
Adaptation Level Theory	Yes	Yes	Separation and contextual extent.	Increase and then decrease in A. Increase in C.	Decrease A. Increase C. Increase contextual length required to produce contrast.	N.P.
Piagetian Theory	Yes	No	NA	Increase and then decrease in A.	Decrease in A.	N.P.
Assimilation Theory	Yes	Yes	Separation and contentual extent.	Increase and then decrease in A illusion. Increase in C illusion.	Decrease in A. Increase in C.	Larger illusion when context between test and response lines

Assimilation (A) Contrast (C) Not applicable (NA) No prediction (NP)

Lateral inhibition theory can be distinguished from the other theories which predict contrast since it predicts contrast to occur from alteration in the degree of separation between test and contextual lines. On the other hand, both adaptation-level theory and assimilation theory predict that contrast can be produced either by change in separation or by alteration in contextual length.

Lateral inhibition theory can also be distinguished from each of the other theories in regards to the effect of contextual length. It predicts that degree of illusion will vary linearly as a function of contextual length; however, each of the other theories predict that a nonmonotonic relation will occur between contextual extent and degree of illusion.

Adaptation-level theory has one feature that distinguishes it from the other theories. It predicts that if separation increases, then a shorter contextual length will be required to produce contrast.

Assimilation theory can be distinguished from the other theories in regards to the effect of position. According to assimilation theory, a larger illusion will occur when the contextual line is positioned between the test and response lines then when it is placed on the opposite side of the test line. None of the remaining theories generate predictions concerning the effects of this variable.

Statement of the Problem

The major aim of this research is the investigation of the separate and interactive effects of contextual extent and spatial separation on the occurrence of assimilation and contrast. Both variables will be manipulated independently in the parallel line configuration shown in Figure 1. With this configuration, contextual extent or spatial separation can be altered without any other variable covarying. Contextual extent will be operationally defined as the length of the contextual line and spatial separation as the perpendicular distance between test and contextual lines. To study the interactive effects of contextual extent and spatial separation both variables will be altered in a factorial design.

The contextual line can be placed either below the test line, so that it will be positioned between the test and response lines, or above the test line. From past research (Pressey, 1971; Pressey & Murray, 1976) it is known that position of context affects degree of illusion, but its role on induction of contrast has not been investigated. Therefore, this research will also examine the influence of position on contrast.

The final objective of the present research is to evaluate current theories of illusions. As shown above, current theories generate different predictions in regard to the effect of alteration of contextual extent and spatial separation. Therefore, the present research will permit examination of current theories by comparison of predictions with obtained findings.

Experiment I

Method

Subjects. Twenty-seven men and women from introductory psychology courses at the University of Manitoba served as subjects. The students were recruited with sign-up booklets distributed within classrooms and received credit towards grades for participation. Only those students with normal, or corrected to normal vision, were invited to take part.

Apparatus. A PDP-8/A computer generated displays and performed all scoring and randomization functions. Displays were plotted on a Textronix 602 point plotter. Each experimental display consisted of three parallel lines; namely, a 21.6 mm test line, a contextual line, and a response line. The perpendicular distance between the test and response lines was 42 mm. This value of the display was chosen, since with a viewing distance of 17.6 cm, the components of the display subtended approximately the same visual angle as used in previous research with the parallel lines configuration (Pressey & Murray, 1975).

A control display was also viewed by subjects. (Chapter 1 in Appendix A discusses control displays.) This display was identical to experimental configurations except that it consisted of two lines; namely, the test and response lines. The control display was used to estimate the degree of response bias produced by subjects, since, in some instances, the degree of bias can be quite substantial (See for example, Brigell et. al., 1977).

Design. The experiment used a 2 x 4 x 9 x 9 mixed design. The variables of position, separation, and contextual length were manipulated within subjects and order of presentation of contextual lengths was varied among groups of subjects. The variable of position refers to the placement of the contextual line. It was placed on either the same side of the test line as the response line or on the opposite side.

Separation, the perpendicular distance between test and contextual lines, consisted of four values; namely, 2.1, 4.2, 8.4, and 14.7 mm. These values encompassed and extended the range of separations used in previous research by Pressey and Murray (1976). In their study the maximum degree of separation was 4.09 degrees of visual angle; whereas, in the present research the maximum degree of separation was 4.76

degrees of visual angle.

Length of contextual lines ranged from 22.80 to 75.00 mm. The lengths were 22.80, 24.25, 27.15, 31.50, 37.30, 45.55, 53.25, 63.40, and 75.00 mm. These lengths were chosen, on the basis of past research, to encompass the entire range of lengths producing assimilation and to extend into the range of lengths where contrast might be found.

Order of presentation of contextual length was used as a blocking variable. Nine different sequences were generated with a one-step cyclic permutation (Winer,1971, p. 690). The first sequence commenced with the shortest contextual length. Then the length of the contextual line was increased by one step for each of the succeeding blocks. The second sequence commenced with the second shortest contextual length and then the length of the contextual line was increased, in each of the succeeding blocks, by one step until the ninth block where the shortest contextual length was placed. The remaining seven sequences were constructed following the same progression. Within each block of trials the two levels of position and the four levels of spatial separation were varied randomly.

The decision to block over the variable of contextual extent was made in consideration of the fact that practice affects degree of illusion (Judd, 1898). Furthermore, it was thought that since the one-step cyclic permutation used to construct the orders ensured that each contextual length appeared an equal number of times in each block position, that effects of practice on the variable of contextual extent could be minimized.

Procedure. Subjects arrived at the testing room in pairs. Each subject was then randomly assigned to one of nine different orders of blocks. Three subjects were assigned to each of the nine different sequences. After the task was explained, one subject commenced the task while the second rested. After the first subject completed his (her) first block of trials, the second commenced his (her) first block of presentations while the first rested. The pair of subjects then alternated between test and rest states until each had completed nine blocks of trials.

Subjects, when tested, placed their chin on a rest to minimize head movements and to keep viewing distance constant at approximately 17.6 cm.

Within each block, nine different displays were viewed. One display was a control figure and eight displays were experimental figures. Within each block of presentations, subjects viewed two consecutive presentations of each of the nine different displays. On the first presentation of a display, the initial length of the response line was randomly made either shorter or longer than the test line. For the second presentation, the response line was made longer, if on the first presentation it was shorter than the test line, by the same amount that it had initially been smaller. If on the first showing, the response line was longer than the test line, on the second presentation the response line was made shorter than the test line by the same amount that it had been longer. The initial length of the response line varied randomly between 5 and 9.65 mm, in .15 mm steps, from the length of the test line.

Subjects were told to adjust the length of the response line so that it appeared equal in length to the test line. Alteration of length was accomplished through depression of buttons. Two buttons served to increase or decrease, respectively, the length of the response line by .15 mm. When the subject was satisfied that response and test lines appeared to be of equal length, (s)he depressed a third button to terminate the trial and to commence a new one. A brief delay of approximately 2 seconds was inserted between trial presentations to allow the trace on the point plotter to dissipate completely before the start of a new trial.

The left point of the response line varied randomly among trials. It was offset randomly, in steps of .15mm, between 5 and 9.65 mm to the left or to the right of an imaginary line drawn perpendicular from the left point of the test line. This prevented subjects from aligning the end points of the test and response lines while performing their task.

Results and Discussion

Analysis of control scores. For each subject, responses to each display were averaged. Then an initial statistical analysis was conducted to determine if the experimental design affected responses to control scores. A group (sequence of presentation of contextual length) by contextual length block (9 by 9) ANOVA (Dixon & Brown, 1979) indicated that neither group, $F(8, 18)=0.51$, $p >.05$, nor contextual length block, $F(8, 144)=1.46$, $p>.05$, nor the group by contextual length block interaction, $F(64, 144)=1.30$, $p>.05$, was statistically significant. Therefore, the testing sequence, the contextual length presented within the same blocks of trials as the control display, and the interaction of sequence and contextual length block were not found to affect responses to control displays.

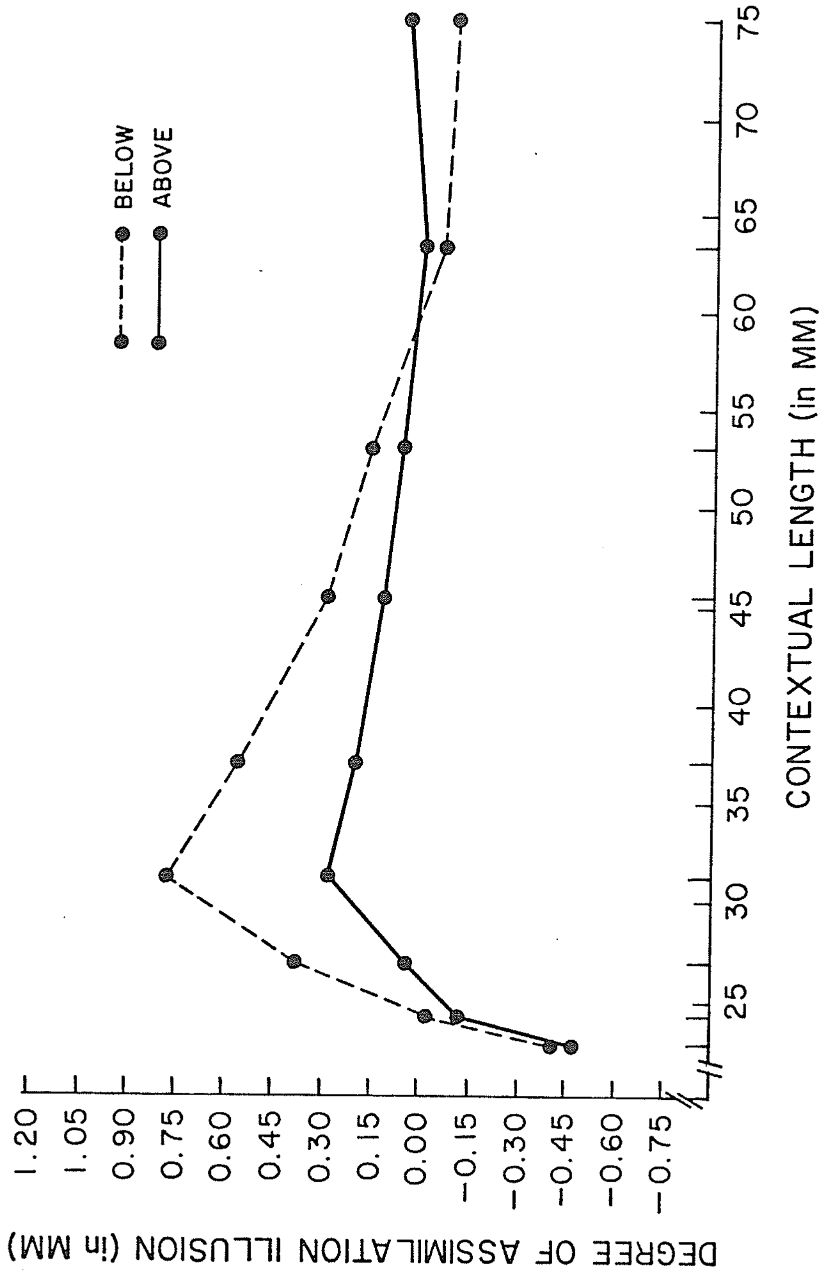
Calculation of illusion scores. For each subject, control scores were subtracted from responses to each experimental display to provide illusion scores. Since the initial analysis (see above) failed to reveal any statistically significant effect of experimental design, an average control score, which was calculated by averaging control scores across each block of trials, was used in the determination of illusion scores. Positive illusion scores indicated assimilation and negative illusion scores indicated contrast.

Analysis of illusion scores. Illusion scores were analyzed with a 2 (position of contextual line) x 4 (separation) x 9 (contextual length) ANOVA. Since an initial analysis indicated the assumption of compound symmetry to be violated for each of the *F* tests with more than one degree of freedom in the numerator, the Geisser-Greenhouse technique (Winer, 1971, p.523-524) was used to evaluate all *F* ratios. Consequently, reduced degrees of freedom were used to assess the level of statistical significance of each *F* test.

The ANOVA indicated that the main effects of position $F(1, 26)=$ $=10.04$, $p<.01$, separation, $F(1, 26)=4.75$, $p<.05$, and contextual length, $F(1, 26)$, $p<.05$, and the interactions of separation with length, $F(1, 26)$, $p<.05$, and of position with length, $F(1, 26)=7.66$, $p<.01$ were statistically significant.

Analysis of the position by length interaction. Figure 10 shows that, regardless of the position of the test line, the degree of assimilation illusion initially increases and then decreases as the length of the contextual line increases. Figure 10 also reveals a substantial degree of separation between the two curves. For short and long contextual lengths the two curves coincide, however, for moderately long contextual extents degree of illusion is substantially greater when the contextual line is placed between the test and response lines than

Figure 10: Degree of assimilation illusion as a function of position and contextual extent.


BELOW
ABOVE
DEGREE OF ASSIMILATION ILLUSION (in MM)
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
−0.15
−0.30
−0.45
−0.60
−0.75
25
30
35
40
45
50
55
60
65
70
75
CONTEXTUAL LENGTH (in MM)

when it is placed on the side of the test line opposite to the response line.

Trend analysis (in this analysis, as in other trend analyses discussed below, a log transformation was performed on the variable of contextual extent)[1] confirmed that position modulated the effect of contextual length. The analysis revealed statistically significant linear, $F(1,26)=14.45$, $p<.05$, quadratic, $F(1,26)=20.70$, $p<.05$, and cubic, $F(1, 26)=19.09$, $p<.05$, components of the position by length interaction. Two additional post hoc trend analyses, with alpha set to .01 to control for Type 1 errors, were then conducted across the two levels of position. They revealed that the nonmonotonic trends displayed in Figure 10 were reliable. In the above position, the linear $F(1, 26)=7.04$, $p<.01$, quadratic, $F(1, 26),=15.41$, $p<.01$, and the cubic, $F(1, 26)=15.41$, $p<.01$, components were statistically significant. In the below position, the quadratic, $F(1, 26)=41.50$, $p<.01$, and the cubic, $F(1, 26)=67.04$, $p<.01$, components were statistically significant.

The interaction between position and length is, in part, consistent with predictions made by assimilation theory. The theory predicts larger assimilation illusions when the contextual line is positioned between test and response lines then when it is placed on the side of the test line opposite to the response line and, by and large, the results do support this prediction.

Analysis of the separation by contextual length interaction. Trend analysis on the separation by length interaction revealed that the effects of separation varied as a function of contextual length and that the effects of contextual length varied as a function of separation. The analysis indicated that the quadratic, $F(1, 26)=38.79$, $P<.05$, and the cubic, *F*(1, 26)=25.38, *P*<.05, components of contextual length varied as a function of the linear component of spatial separation.

In Figure 11, where degree of illusion is plotted as a joint function of contextual length and separation, the slope of the curve between degree of illusion and level of separation varies as a function of contextual extent. The slope is positive with the shortest contextual extent, negative with moderately long contextual lines, and is zero with long contextual lengths. Since a positive slope with the shortest contextual length indicates a decrease in contrast illusion and negative slopes found with the moderately long contextual extents indicate a decrease in assimilation illusion, the overall pattern of results reveal an inverse relation between degree of illusion and level of separation.

Post hoc trend analyses, which examined trend components up to the cubic level, were then conducted across each of the levels of separation. To control for Type I errors, an alpha level of .01 was used as a criterion in accepting an *F* ratio as statistically significant.

Table 2 shows that the quadratic and cubic components of the effects of contextual length were statistically significant with degree of separation equal to 2.1, 4.2, and 8.4 mm. With the greatest degree of separation, 14.7 mm, the trend components were not statistically significant. Table 2 shows, therefore, reduction of the effect of contextual length with large separations. Furthermore, if the magnitude of the *F* ratios can be interpreted to indicate the level of the effect of a trend component, then another conclusion can be gleaned from Table 2; namely, as separation increases, the function between degree of illusion and contextual length becomes flatter. This conclusion is substantiated in Figure 12, where the interaction is shown with

Figure 11: Degree of assimilation illusion as a function of contextual extent and spatial separation.

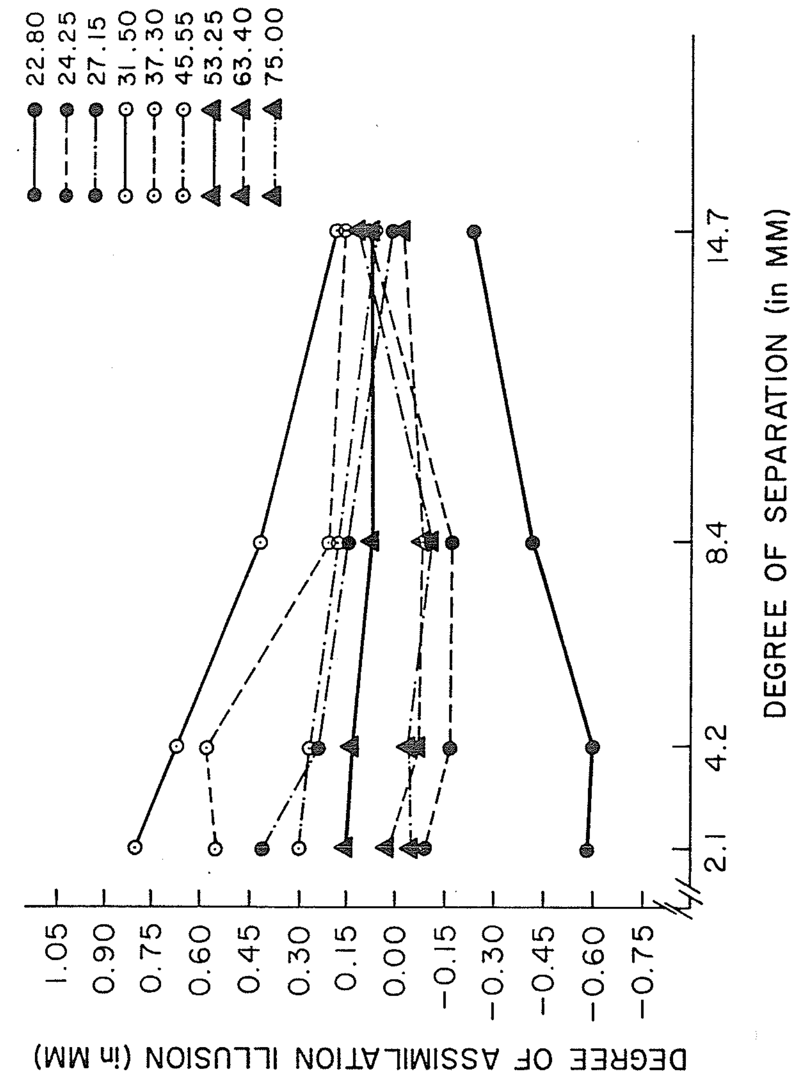

DEGREE OF ASSIMILATION ILLUSION (in MM)
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
−0.15
−0.30
−0.45
−0.60
−0.75
2.1
4.2
8.4
14.7
DEGREE OF SEPARATION (in MM)
22.80
24.25
27.15
31.50
37.30
45.55
53.25
63.40
75.00

TABLE 2: Trend analysis on the interaction between contextual length and spatial separation.

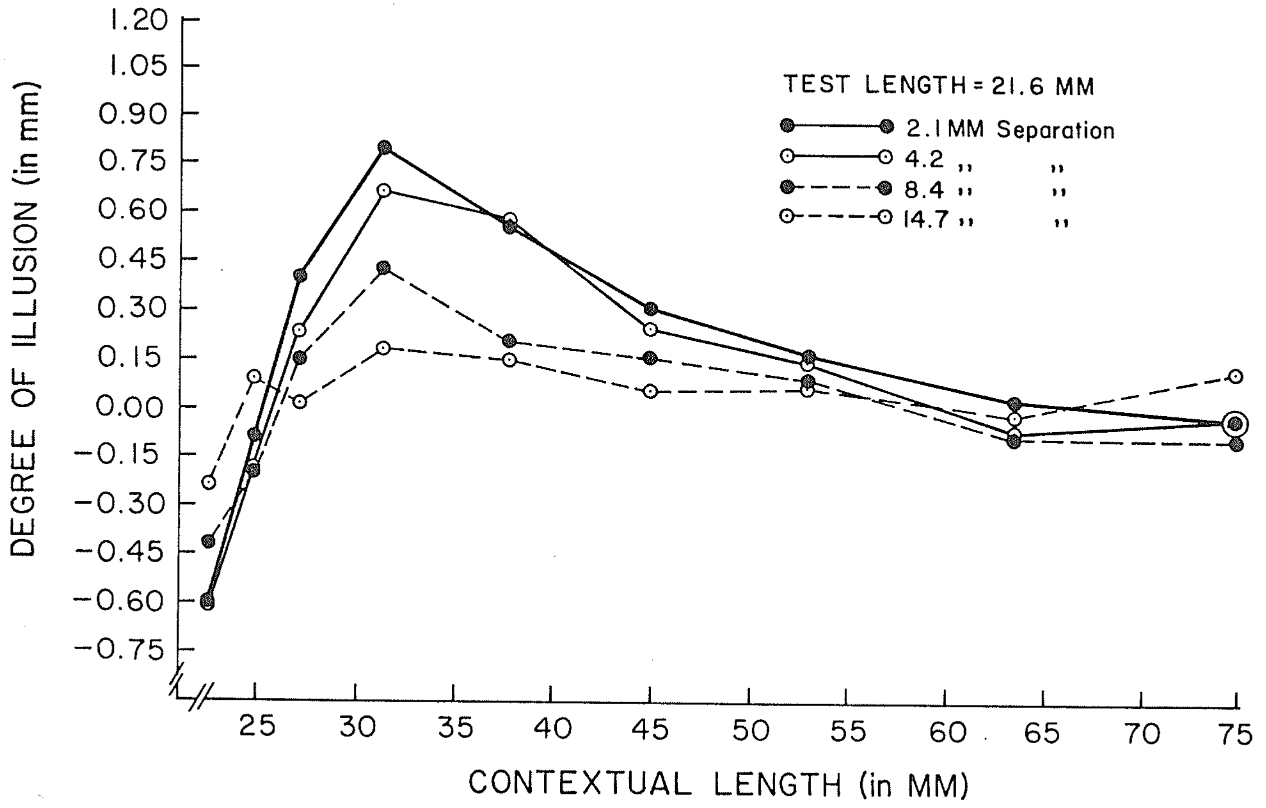
TABLE 2

Length as a Function of Separation

Separation	Linear	Quadratic	Cubic
2.1 MM	0.34	35.30	49.88
4.2 MM	1.41	40.49	50.47
8.4 MM	0.80	18.75	18.61
14.7 MM	0.68	4.14	7.16

A value of 7.72 is required to be significant at the .01 level with 1, 26 degrees of freedom.

Figure 12: Degree of assimilation illusion as a function of spatial separation and contextual extent.


TEST LENGTH = 21.6 MM
2.1MM Separation
4.2 " "
8.4 " "
14.7 " "
DEGREE OF ILLUSION (in mm)
1.20
1.05
0.90
0.75
0.60
0.45
0.30
0.15
0.00
−0.15
−0.30
−0.45
−0.60
−0.75
25
30
35
40
45
50
55
60
65
70
75
CONTEXTUAL LENGTH (in MM)

contextual extent plotted along the abscissa.

The general pattern of results displayed in Figure 11 is fairly consistent with predictions generated from adaptation-level, assimilation, framing, and Piagetian theories, since they predict the nonmonotonic relation between contextual extent and degree of illusion. The general pattern of results is not consistent with lateral inhibition theory since it predicts a linear relation between contextual extent and degree of illusion.

The specific pattern of results displayed in Figures 11 and 12 is not entirely consistent with with any theory of illusions. From Piagetian theory, it is expected that a fairly substantial difference in degree of illusion would separate the four curves depicted in Figure 12. However, with contextual lengths of 53.25 mm and longer, the curves coincide. The findings with the shortest contextual extent is also inconsistent with predictions made by assimilation and and adaptation-level theories. The theories predict the occurrence of a negative slope between degree of assimilation illusion and separation. It is clear from Figure 11, however, that the slope of the function for the short contextual extent is positive, but the direction of the illusion is one of contrast.

Additional post hoc analyses. The most unexpected aspect of the results, was the suggestion contained in Figures 10, 11, and 12 that contrast occurred with the shortest contextual extent. To test if the amount of contrast was statistically significant, Dunn's test (Keppel, 1977), with the alpha level set to .01, was used. The first analysis examined the 22.8 mm display, across the two levels of position, and revealed that the illusion was statistically significant (critical difference = .32mm) in both the above and between positions of the contextual line. The second analysis examined the 22.8 mm display across the four levels of separation and found statistically significant illusions for the 2.1, 4.2, and 8.4 mm separations but not for the 14.7 mm separation (critical difference =.33mm). Therefore contrast occurred more readily for short than for long separations and just as readily for either the below or the above position of the contextual line.

It could be argued that the lack of contrast with long contextual extents is due to contrast occurring at different long contextual extents for different subjects. However, visual inspection of the individual means fail to substantiate this arguement.

Experiments II and III

There are two surprising findings in Experiment I; namely, the occurrence of contrast with the 22.8 mm long contextual line display and the lack of contrast with either long contextual lines or with large separations between test and contextual extents. These findings are incompatable with contemporary theories of illusions. However, it is possible that the one-step cyclic permutation used to order the blocks of contextual lengths may have played a major role in generating the pattern of results. In eight of the nine orders, 22.8 mm contextual line displays were preceded by 75 mm contextual line displays and in eight of the nine orders 75 mm contextual line displays were preceded by blocks with shorter contextual extents. Thus, if carryover effects exist between blocks of different length, there was ample opportunity for it to have occurred in Experiment I. Therefore, to check on the reliability of the results obtained in Experiment I, two additional experiments, which minimized the possibility of carryover effects, were designed. In Experiment II the two shortest contextual extents and in

Experiment III the two longest contextual extents were reinvestigated.

Method

Subjects. Forty men and women were recruited from an intersession introductory psychology class at the University of Mantitoba. Participants were required to have good vision, either with or without glasses, and received credits towards their final grades for performing as subjects. Twenty subjects were asigned to each experiment.

Apparatus. The equipment used in Experiment I performed the same functions in Experiments II and III.

Design. Experiments II and III each used a 2x2x2x4 within subject design. The variables were blocks of trials, length of contextual line, position of contextual line, and separation. As in the first experiment, the separations were 2.1, 4.2, 8.4, and 14.7 mm and the contextual line was placed either between the test and response line or on the side of the test line opposite of the response line. Contextual lengths of 22.80 and 24.25 and of 63.40 and 75.00 mm were used in Experiments II and III, respectively.

The variable of blocks of trials referred to the number of separate, complete presentations of experimental and control displays. Each subject viewed two randomly ordered presentations of sixteen experimental and two control displays. Two different presentations of the control displays occurred in each block of trials. The increase in the number of control displays permitted a more stable estimate of control responses.

Procedure. The procedure was the same as that used in Experiment I with the exception that subjects were randomly assigned to experiments instead of to sequence orders.

Results and Discussion

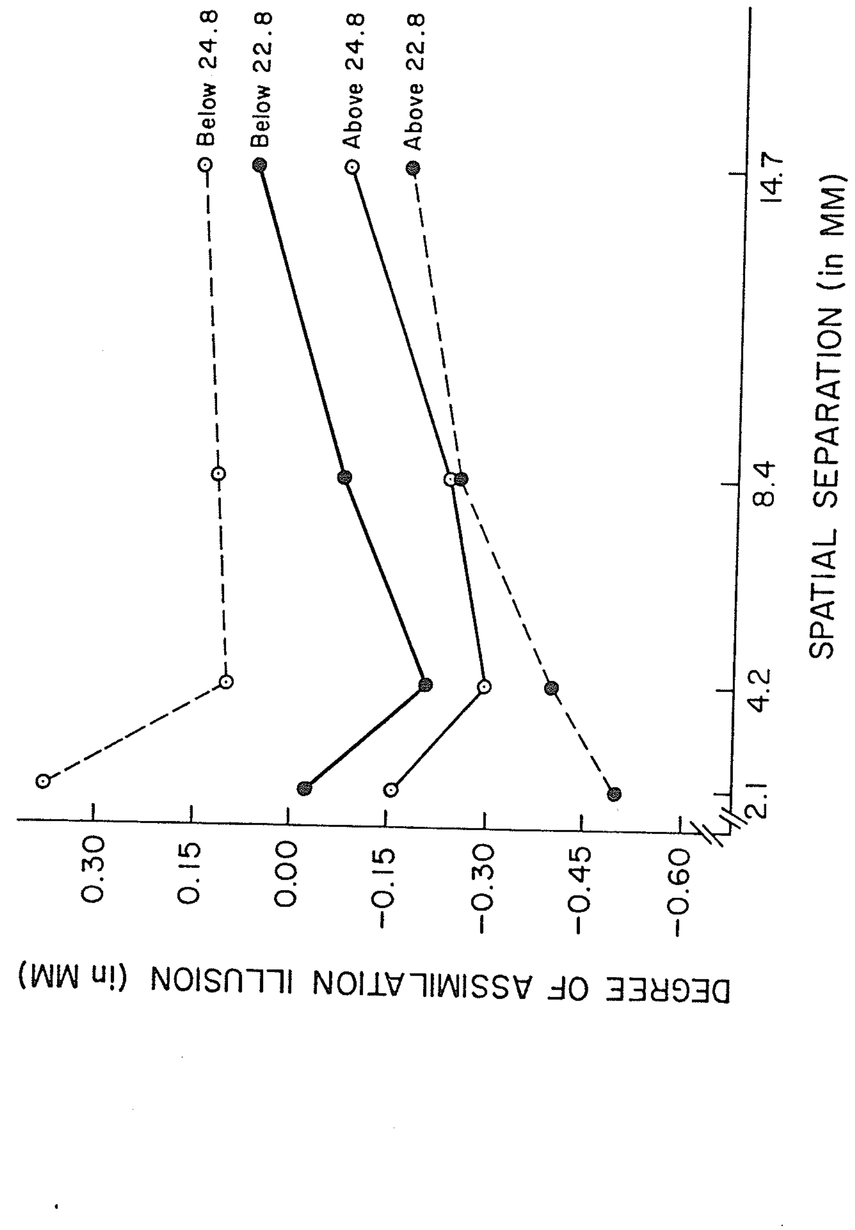
Analysis of control scores. For each subject, responses produced to each presentation of a display were averaged. Then responses to control displays made within each block of trials were averaged. These responses were then submitted to a one-way ANOVA on the variable of block. The ANOVA did not reveal a significant effect of block for either Experiment II, F(1, 19)=1.098, p>.05, or Experiment III, F(1, 19)<1, p>.05. Thus, practice was not found to have a significant effect on control scores.

As in Experiment I, average control scores were not equal to 0 mm. In Experiment II, which was conducted with the short contextual lines, the average control score was equal to .48 mm. In Experiment III, which was conducted with the long contextual lines, the average control score was equal to .16 mm. The difference between the two indicated that the average control score was affected by type of display and can be explained on the basis of adaptation-level theory (Helson, 1964).

Calculation of illusion scores. For each subject an average control score was calcuated. Then, control scores were subtracted from responses produced to experimental displays to provide illusion scores.

Analysis of illusion scores. For both experiments, 2 x 2 x 2 x 4 ANOVA's on the variables of block, length, position, and separation were conducted. For Experiment II, the main effects of length, F(1, 19)=15.21, p<.05, position, F(1, 19)=8.87, p<.05, and separation, F(3, 57)=3.53, p<.05, were statistically significant. Figure 13, where the results of Experiment II are depicted, reveals that contrast is more likely to occur with the 22.8 mm contextual line, with the above position of the contextual line, and with short separations between test

Figure 13: Degree of assimilation illusion as a function of position, length, and spatial separation.


DEGREE OF ASSIMILATION ILLUSION (in MM)
0.30
0.15
0.00
−0.15
−0.30
−0.45
−0.60
SPATIAL SEPARATION (in MM)
2.1
4.2
8.4
14.7
Below 24.8
Below 22.8
Above 24.8
Above 22.8

and response lines.

The ANOVA, conducted on Eperiment III, revealed that the main effect of position, F(1,19)=18.695, $p<.05$, and the interaction of position with separation were statistically significant. Trend analysis on the position by separation interaction indicated that the quadratic component of separation varied as a function of position, F(1, 19)=6.53, $p<.05$. Figure 14 shows, for the above position of the contextual line, that degree of illusion initially increased and then decreased as separation increased; however, for the below position, degree of illusion initially decreased and then increased as separation increased. The finding that a greater degree of assimilation illusion occurs with the above position is opposite to predictions made by assimilation theory.

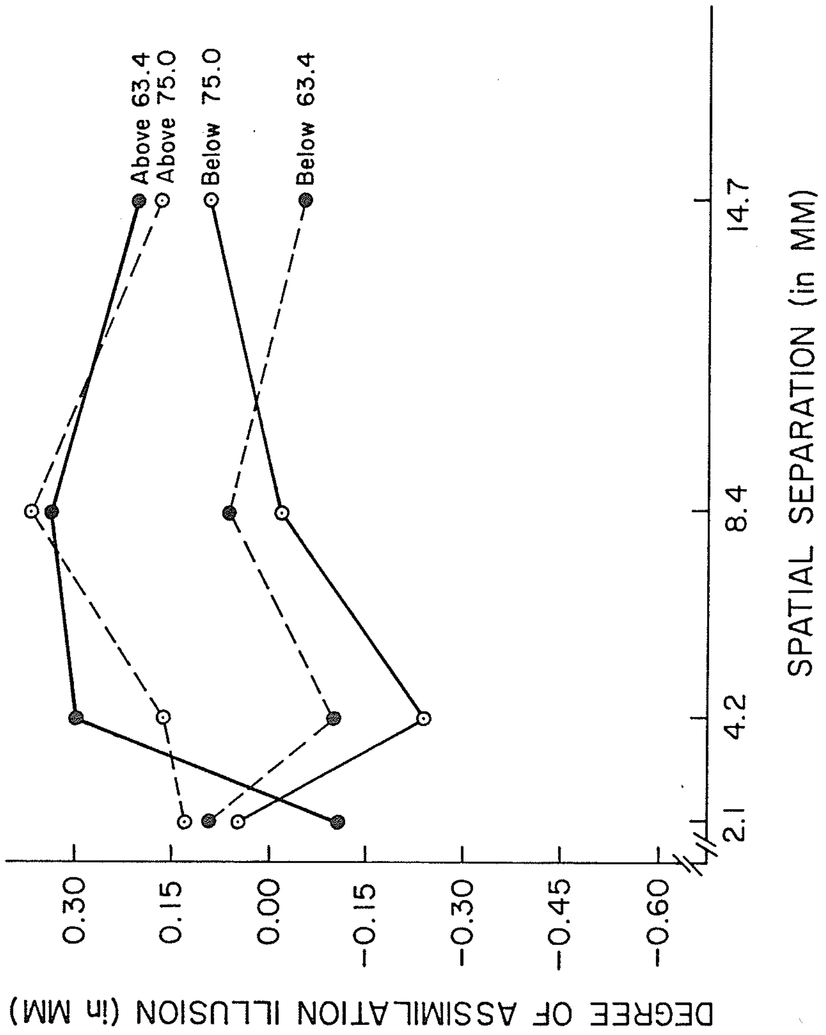
Generally, the pattern of results confirm those found in Experiment I. Contrast occurs with short contextual lines but not with long ones.

Experiment IV

One source of concern about the results of Experiment II involves the role of the control displays in the determination of contrast. First, the length of the response which matches the test line in the control display is sensitive to contextual extents of the experimental displays. The shorter the contextual extent the longer the response. Second, the maximum amount of contrast induced by the short contextual lines is about equal to the amount of overestimation of the test line in control displays. Therefore, the evidence for contrast is produced from the control displays and the control display itself is susceptible to contextual effects produced by the displays under evaluation.

The logic which underlies the use of control displays assumes that

Figure 14: Degree of assimilation illusion as a function of position, contextual length, and spatial separation.


DEGREE OF ASSIMILATION ILLUSION (in MM)
0.30
0.15
0.00
-0.15
-0.30
-0.45
-0.60
2.1
4.2
8.4
14.7
SPATIAL SEPARATION (in MM)
● Above 63.4
○ Above 75.0
○ Below 75.0
● Below 63.4

whatever distorting effects are present in responses produced to control displays are also inherent in responses produced to experimental displays. If this assumption is correct, and there is no reason to believe that it is not, then the conclusions reached previously are reasonable. However, because of the unexpected findings of contrast with short contextual extents, the role of the control displays in determining contrast, and of the theoretical importance of the findings it seems mandatory to verify the generality of the findings with the short contextual extents. Consequently, it may be worthwhile to reexamine responses produced to displays with short contextual extents with a different method to verify the previous conclusions.

In the previous experiments subjects were required to alter the length of the response line. If the procedure of altering line length affects responses then it may be necessary to provide a task in which subjects do not actually change the length of the response line but rather simply indicate if the response line appears either longer or shorter than the test line. Therefore, the fourth experiment investigated responses produced to displays with short contextual extents. This time subjects were required to judge the relative length of the test and response lines.

Method

Subjects. Twenty-four students enrolled in first year psychology courses at Brandon University participated. Students received credit toward their final grades for taking part in the study.

Apparatus and displays. A Cromenco-Z2 computer system generated displays on a Hewlett-Packard 1333A X-Y plotter. Experimental displays consisted of a 22.8 mm contextual line and 21.6 mm test and response lines. Control displays consisted of test and response lines. The only difference between the displays used in this study and the previous experiments involved the placement of the test and response lines. In this study the response line was placed directly below the test line instead of off to one side.

Design. A 2x4 within subject design was used. The variables were position of contextual line (either above or below the test line) and spatial separation. The values of separation were the same as those used in the previous experiments, namely, 2.1, 4.2, 8.4, and 14.7 mm.

Procedure. Subjects viewed three randomly ordered series of displays. Thus, each display was judged three times by each subject. Each series consisted of eight experimental and one control displays. Displays were observed from a viewing distance of 17.8 cm. Subjects stated "top" if the test line appeared longer than the response line or "bottom" if the response line appeared longer than the test line. After the experimenter recorded the response a different display was presented.

Results and Discussion

Calculation of illusion scores. The first step in the analysis consisted of scoring each response as a 1 or as a 0 to indicate either overestimation or underestimation, respectively, of the test line. Then for each subject, responses to each display were summed across trials. Next control scores were subtracted from responses produced to experimental figures. The remainder was then divided by three (the number of trials) to provide average illusion scores.

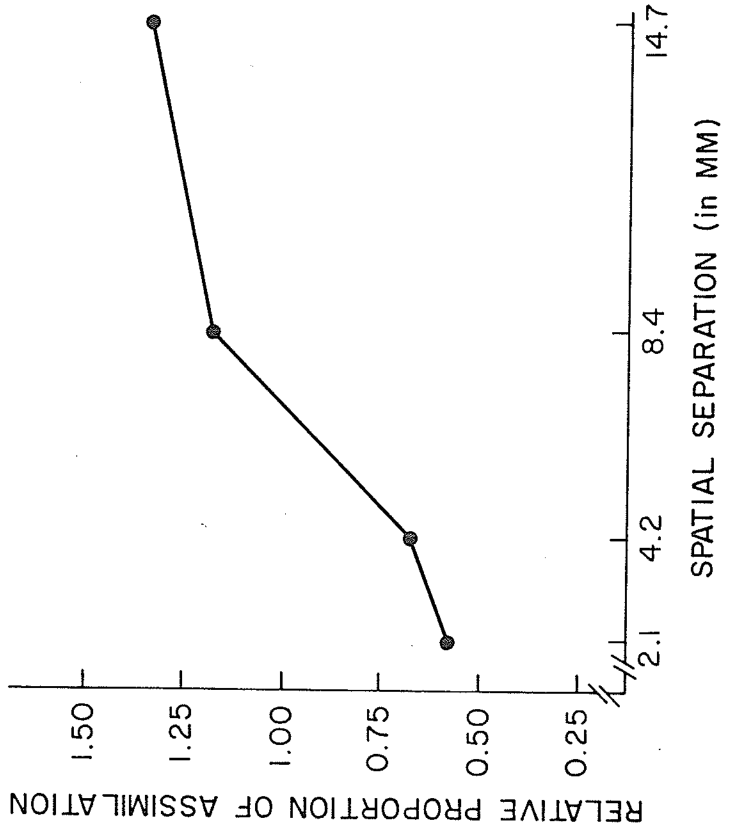
Statistical analysis. The average illusion scores were analyed with a 2 (position) by 4 (separation) ANOVA. From the ANOVA it was found that the effects of separation, $F(3,69)=5.71$, $p<.01$ were statistically significant; however, neither position nor the position by separation interaction were statistically significant.

Figure 15 presents the relative proportion of assimilation to contrast responses. It is clear from this figure that with small separations between test and contextual extent that contrast predominates and that the frequency of assimilation increases with increases in spatial separation. By and large then, the results of this study confirm and clarify the previous findings; namely, contrast occurs with small differences in length between test and contextual lines and with small degrees of separation. While there was a greater number of contrast responses with the above position than with the below position, as in Experiment II, the variable of position did not reach statistical significance. Accordingly, position of the contextual line was not a major determinant of the contrast observed in the present experiment.

Experiment V

One puzzling feature of the findings is the lack of contrast with either long contextual extents or with large separations between test and contextual lines. The lack of contrast is at odds with previous findings obtained with Baldwin (Pressey & Wilson, 1980), Delboeuf (Keats, 1964), Muller-Lyer (Restle & Decker, 1977), and Titchener circles (Girgus *et. al.*, 1972) configurations. Those findings indicate that contrast occurs when contextual extent becomes long or spatial separation becomes great. The lack of contrast with long contextual extents or a large degrees of spatial separation is also at odds with contemporary mathematical models of illusions. In these models, quanti-

Figure 15: Relative frequency of assimilation to contrast. Values below 1, indicate contrast. Values above 1, indicate assimilation.


RELATIVE PROPORTION OF ASSIMILATION
1.50
1.25
1.00
0.75
0.50
0.25
2.1
4.2
8.4
14.7
SPATIAL SEPARATION (in MM)

tative variables such as contextual extent or spatial separation are assumed to control assimilation and contrast. Perhaps this assumption is incorrect. It is possible that a qualitative variable controls contrast. If a qualitative variable instead of a quantitative variable induces contrast, then differences in figural components between displays used in the present series of studies with those used in other experiments could be responsible for contrast found with other configurations.

One major difference between the parallel line configuration and those which exhibited contrast in previous research concerns the nature of contextual features. In the Muller-Lyer, Baldwin, as well as other configurations, contextual features occur both above and below the test extent; in the parallel line display used in the present study the context is placed either above <u>or</u> below the judged extent. It is plausible that "surroundness" may play a role in inducing contrast.

One way that "surroundness" can be created in the parallel lines display is to present contextual lines simultaneously above and below the test extent. Therefore, in the fifth and final experiment the effect of surroundness was studied in parallel line displays which consisted of one test line and two contextual lines.

<u>Method</u>

<u>Subjects.</u> Twenty-four students enrolled in an intersession, introductory psychology course at the University of Mantitoba took part. Students received credit towards their final grades for participation.

<u>Apparatus and displays.</u> The equipment used in Experiments I, II, and III performed the same functions in the present experiment.

Experimental displays consisted of a 21.6 mm test line, a response line of variable length, and two contextual lines. One contextual line was placed above the test line and the second was positioned below. In each display the contextual lines were of equal length and of the same degree of spatial separation from the test line. In control displays the contextual lines were omitted.

Design. A 6 x 3 x 9 mixed design was used. The within subject variables were spatial separation and contextual length. Three of the previously used values of separation; namely, 2.1, 8.4, and 14.7 mm, and the 9 lengths of contextual extent used in Experiment I were selected. The between subject variable consisted of the sequence in which spatial separation was varied. Four subjects were assigned to each of the six different permutations of the three levels of separation.

Procedure. Subjects arrived to the testing room in pairs. Each subject was then randomly assigned to one of the orders in which spatial separation was varied.

Subjects were presented with three blocks of trials. Spatial separation was varied between blocks and contextual length was varied within blocks. Each block consisted of randomly ordered presentations of experimental and control displays. As in Experiment II and III control displays were viewed twice within each block of trials.

The same procedure used in Experiment I, II, and III was used to collect responses.

Results and Discussion

Analysis of control scores. Responses to each display were averaged. Then control scores were analyzed in two separate ANOVA's. In the first, they were analyzed as a function of block and of group (sequence). In the second, the control scores were analyzed as a function of group (sequence) and of degree of spatial separation used in each block. Neither ANOVA revealed any statistically significant main or interaction effects. Therefore, sequence, spatial separation within a block, group, and their interactions failed to affect control scores.

Calculation of illusion scores. For each subject average control scores were calculated. Then control scores were subtracted from responses made to experimental displays to provide illusion scores.

Analysis of illusion scores. Illusion scores were analyzed with a 3(separation) by 9(contextual length) by 6(group) mixed ANOVA. An initial test revealed that the assumption of compound symmetry was violated for the F tests on the main effect of length and on the interactions of length by group, separation by length, and separation by length by group. Consequently, the Geisser-Greenhouse technique was used as an aid in the assessment of the F tests for those effects. The ANOVA did not reveal any statistically significant main or interaction effects which involved the variable of group. Therefore, sequencing of the order in which spatial separation was manipulated did not affect illusion scores. The ANOVA did demonstrate that the variables of spatial separation, $F(2,36)=3.13$, $p<.05$, and contexual length, $F(1,18)=10.4$, $p<.05$, were statistically significant. With the Geisser-Greenhouse technique the interaction between contextual length and spatial separation did not attain statistical significance, $F(1,18)=2.78$, $p>.05$ but did reach conventional levels of statistical significance when the Geisser-Greenhouse technique was not applied, $F(16,288)=2.78$, $p<.05$.

According to Keppel(1973), when the assumption of compound symmetry is not met the ANOVA is a liberal test; i.e., if the alpha level was set at .05 the probability of rejecting the null hypothesis, given no difference among population means, would be greater than .05. On the basis of Monte Carlo studies, Keppel suggested that the true alpha level would be between .05 and .10. On the other hand, the correction used by the Geisser-Greenhouse technique results in a conservative test; i.e., if the alpha level was set at .05 and given that there were no differences among population means, then the probability of rejecting the null hypothesis would be less than .05. Therefore, with a liberal test the interaction between contextual length and spatial separation would be considered to be statistically significant but with a conservative test it would not. Keppel's advice in this situation is that we should consider the results in light of other findings. This interaction was found in Experiment I and most likely should be considered as a statistically significant finding.

Analysis of the separation by contextual length interaction. Trend analysis revealed that the effects of separation varied as a function of contextual length and that the effects of contextual length varied as a function of separation. The analysis indicated that the linear, $F(1, 18)=6.78$, $p< .05$, and the quadratic, $F(1, 18)=11.88$, $p<.05$, components of contextual length varied as a function of the linear component of spatial separation.

Figures 16 and 17 show two different ways of plotting the interaction between spatial separation and contextual extent. In Figure 16, spatial separation is plotted along the abscissa. The slopes of the curves are very similar to those found in Experiment I, although they do not appear as linear. The addition of a second contextual line, then had little influence on the effects of spatial separation.

Figure 16: Degree of assimilation illusion as a function of contextual extent and spatial separation.

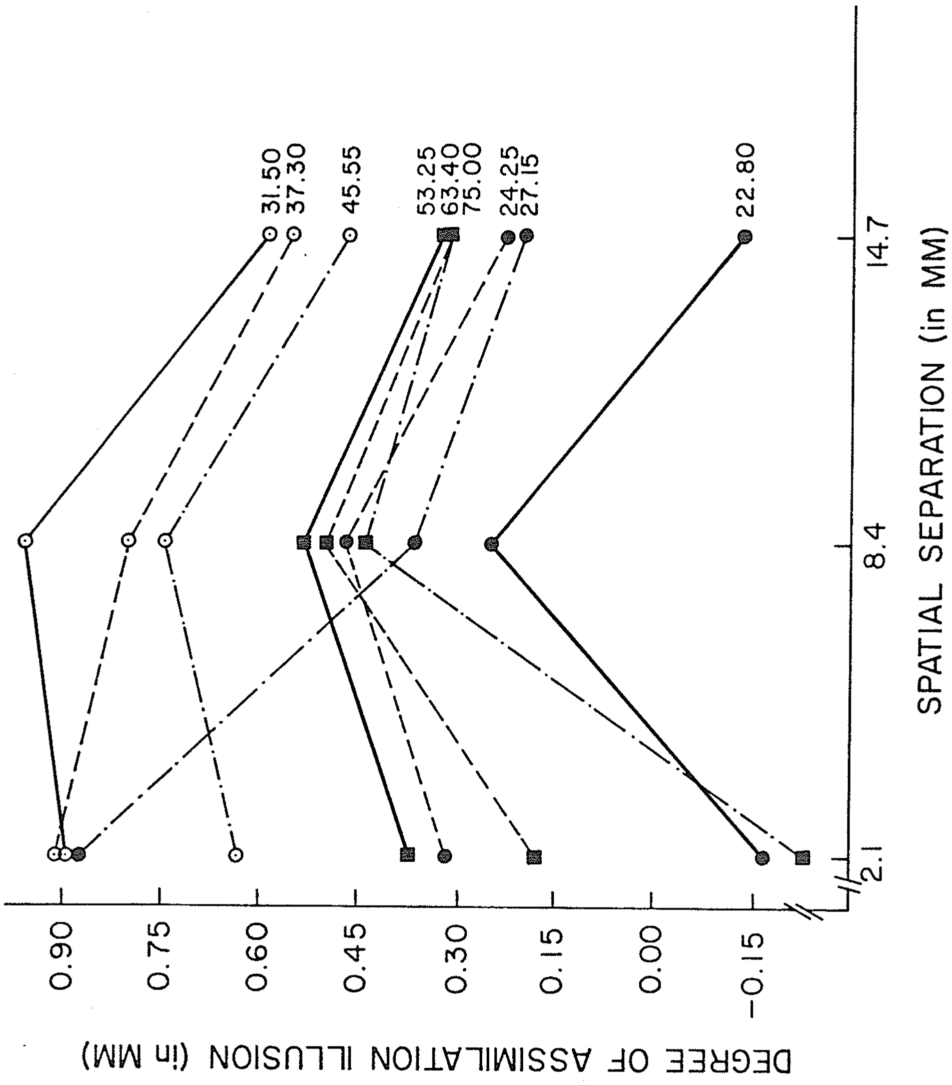
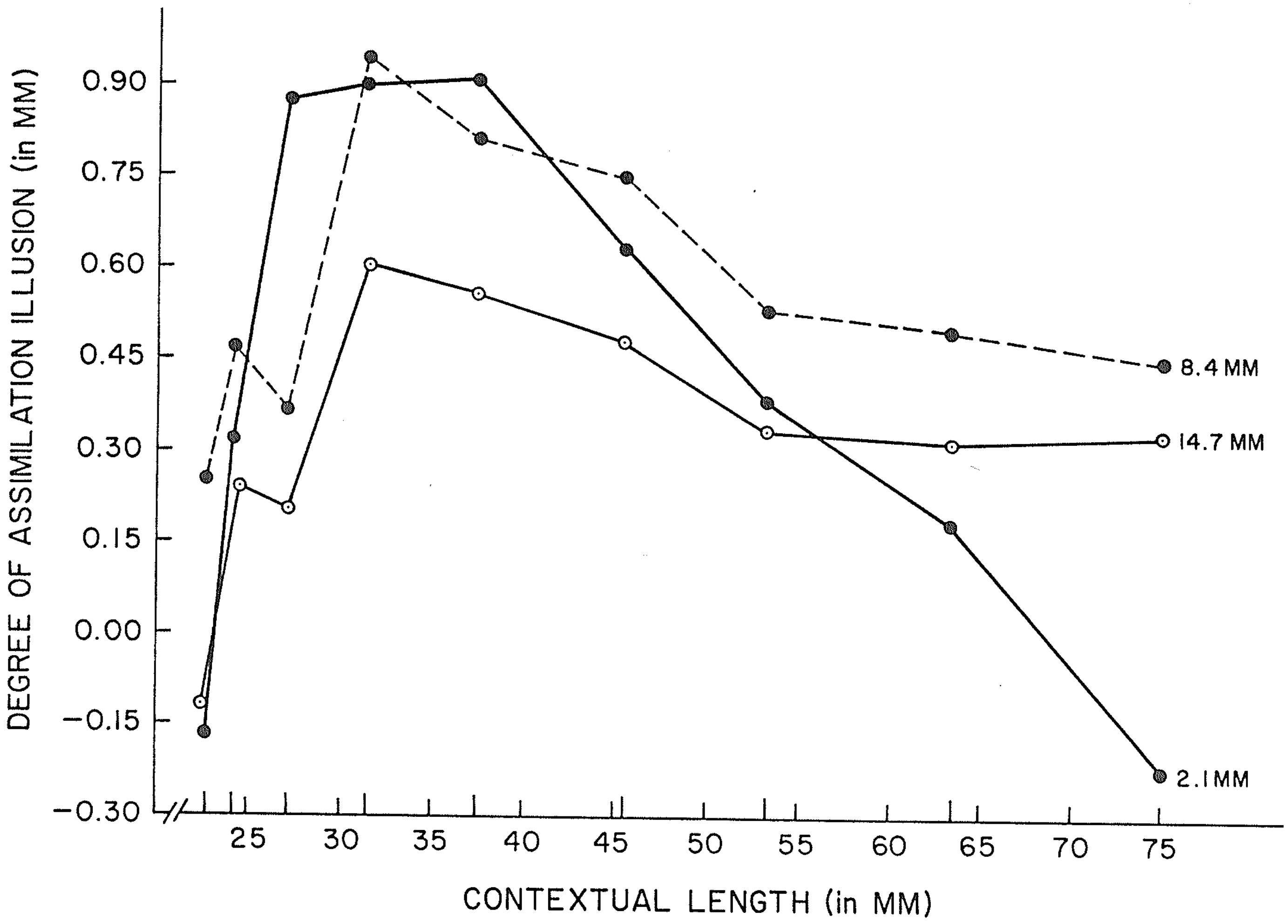

DEGREE OF ASSIMILATION ILLUSION (in MM)
0.90
0.75
0.60
0.45
0.30
0.15
0.00
−0.15
SPATIAL SEPARATION (in MM)
2.1
8.4
14.7
31.50
37.30
45.55
53.25
63.40
75.00
24.25
27.15
22.80

Figure 17: Degree of assimilation illusion as a function of spatial separation and contextual extent.


DEGREE OF ASSIMILATION ILLUSION (in MM)
0.90
0.75
0.60
0.45
0.30
0.15
0.00
−0.15
−0.30
25
30
35
40
45
50
55
60
65
70
75
CONTEXTUAL LENGTH (in MM)
8.4 MM
14.7 MM
2.1 MM

In Figure 17, where contextual extent is plotted along the abscissa, two major points of interest are revealed. First, the inverted u-shaped function between contextual length and degree of illusion is present. The function is very similar to the one obtained in Experiment I. In addition, as in Experiment I, the peak illusion is found with a contextual extent of 31.50 mm. Second, the figure reveals the influence of separation on the effects of varying contextual length. With moderate to large degrees of spatial separation, change of contextual length between 53.25 to 75 mm has little influence on alteration of degree of illusion but with small separations it results in decreased assimilation illusion (Dunn's test, critical difference =.10 mm, $p<.05$). This finding is quite different from the results obtained in Experiment I. In that experiment degree of illusion changed minimally with alteration of length between 53.25 to 75 mm. It seems then, that one major effect of the second contextual line is found with alteration of contextual length with small separations.

In regards to contrast, Experiment V also reveals little evidence of contrast with short or long contextual extents. None of the means which fall into the contrast range of illusion are greater than 1.96 standard errors of the mean away from zero illusion. However the trend in Figure 17 suggests that if longer contextual extents are used for displays with small separations that contrast may occur.

This experiment indicates that "surroundness" may have some influence in altering illusion. It enhances the effect of varying contextual length with small spatial separations; eliminates contrast with short contextual extents; and may produce contrast with contextual lengths longer than the ones used in the present study. However, the introduction of a qualitative variable may be premature because, with the exception of the degree of illusion found with spatial separations of 8.4 mm, the level of illusion induced by displays with two contextual lines was about equal to the average level of illusion found in Experiment I. That is the effect of two contextual lines that are symmetrical about the test line is about equal to the average effect produced by one contextual line when the average occurs across the above and below position. This observation suggests that an averaging mechanism, such as that suggested by Pressey (1967) or by Brigell *et al*, (1977), could be used to interpret some of the results of Experiment V without reference to a qualitative variable.

General Discussion

On the basis of past research and current theories, it was expected that assimilation would occur with small spatial separations and short contextual extents. It was also expected that contrast would be found with large spatial separations and long contextual extents. These expectations were not realized.

Contrast was not reliably observed with long contextual extents. In the initial pair of experiments, little change in degree of illusion resulted when contextual extent was varied from 53.25 to 75 mm. If contrast was to be observed with long contextual extents, then a negative slope between degree of illusion and contextual length would have occurred. The only instance when this was observed occurred with small spatial separations in the final experiment. It seems, then, that if contrast is to be found with long contextual extents, that it would occur only under special circumstances; namely, when contextual elements surround and are positioned close to the test extent.

The most unexpected finding occurred in Experiment I when contrast was observed with short contextual lines. Experiments II and IV confirmed and clarified these observations. They found that small spatial separations and possibly the above position of the contextual line enhanced degree of contrast. These findings appear to be reliable since samples of subjects, experimental design, psychophysical methods, and equipment varied among experiments. Therefore, it is unlikely that the observation was due to either sampling error or from an artifact of the method of data collection.

One question that needs to be answered is why contrast has not been reported previously. Part of the answer involves the use of control displays. In the past, as Brigell _et al_ have noted, control displays often were not included in the design of research. Therefore, response bias may have masked its observation. In the present series of experiments, for example, there was a systematic tendency for observers to make their responses slightly longer that the physical length of the test line for the control displays. Therefore, if response bias had not been taken into account the estimate of degree of contrast would have been diminished.

A second answer may involve selective perception on the part of past researchers. The magnitude of assimilation illusion and the range of contextual extents which produce assimilation may desensitize researchers to small contrast effects which occur over a limited range of conditions. In the results of two separate studies (Lewis, 1909; Restle & Decker, 1977), contrast is exhibited for displays with short contextual extents. In neither study were these observations commented upon nor evaluated statistically.

The third reason concerns the range of contextual extents studied in past research. Many previous studies did not select the ratio of contextual to test extent which produced contrast in the present experiments. In the study which examined most extensively the effects of altering the ratio of contextual to test extent (Brigell et al, 1977) the smallest ratio used was 1.22 : 1. The ratio which produced the most reliable observation of contrast in the present study was 1.05 : 1. Therefore, the conditions which produced contrast in the present study may not have undergone extensive scrutiny in the past.

One consistent finding throughout the studies was the interaction between contextual length and spatial separation. In Experiments I and V it was observed that the influence of contextual length on degree of illusion diminished with an increase in spatial separation. In addition, it was found that the slope between assimilation illusion and spatial separation altered as a function of contextual extent. With short, medium, and long contextual extents the slopes were positive, negative, and flat resepectively. Although the slopes were different the conclusion reached was the same; namely, with increased spatial separation illusion decreased in magnitude. In those instances when the positive slopes occurred, degree of contrast illusion diminished, and for those cases when the negative slopes were found, degree of assimilation illusion became smaller. On the basis of these results one could conclude that spatial separation is a multiplier variable; i.e., it determines degree but not necessarily the type of illusion.

Comparison with previous findings. With the exception of contrast with short contextual extent, the present results confirmed those of previous researchers. As in the present studies previous research has consistently obtained the inverted U-shaped function between degree of illusion and contextual extent. Furthermore the 3:2 ratio of contextual to test extent which produced the largest assimilation illusion was identical to the ratio found by Brigell _et al_. Overall then the results were consistent in regard to the alteration of contextual extent.

The findings were also consistent with those of Pressey and Murray (1976) who altered spatial separation and position of context. As in the present study they found an inverse relationship between degree of illusion and spatial separation. In addition they also found that when the contextual extent was positioned between the test and response lines, a larger illusion occurred than when it was placed on the side of the test line opposite to that of the response line. For moderately large contextual extents, which provided approximately the same ratio of contextual to test extent used by Pressey and Murray, the same findings were obtained. However, larger assimilation illusion occurred with the above position of the contextual line with long contextual extents. Therefore the research has not only replicated previous findings obtained by Pressey and Murray but also has extended them.

Implications for current theories The biggest difficulty posed for current theories is the finding that contrast occurs with short contextual extents. None of the theories as they are presently formulated can account for this finding, although with some modification they may be able to.

Framing theory. Framing theory was developed to account only for the effects of contextual length on degree of illusion. With the exception of the findings with the short contextual extents, the results were compatible with theoretical predictions. As required by the theory, the inverted U-shaped function between contextual length and degree of illusion was observed. Also, as predicted by this theory, contrast was not observed with long contextual extents.

One difficulty for framing theory is that it needs to be expanded to take into account the effects of spatial separation. One way that this may be accomplished is by assuming that the level of firing of units which respond to the test extent and which are affected by contextual extents is inversely related to spatial separation. Certainly this assumption is consistent with findings involving the neurophysiology of the visual system, at least at the retinal level (Uttal, 1973). Such a mechanism could possibly provide a satisfactory explanation of the effects of spatial separation.

Lateral inhibition theory. Brigner's (1977) explanation of illusions was not supported with the present findings. First, the theory predicted that a linear function would occur between degree of illusion and contextual length and a nonmonotonic function occurred. Second, according to the theory, spatial separation controls the occurrence of assimilation and contrast. With small spatial separations assimilation is predicted and with large separations contrast is expected. The results were opposite to this prediction.

Adaptation-level theory. Adaptation-level theory (Restle & Decker, 1970; Restle, 1978) faces several difficulties with the data. Foremost is the finding of contrast with short contexual extents. There appears to be no simple way to modify adaptation-level theory to explain this finding. In addition, there appears to be no simple way to modify the theory to account for the finding that degree of illusion is inversely related to spatial separation since the theory was developed to explain alteration in perceived extent and not alteration in degree of illusions. The theory could possibly explain the inverse function for either assimilation or contrast but not both. The final difficulty that the theory encounters concerns the effects of spatial separation with long contextual extents. From the theory, it would be expected that either contrast should occur more readily or that the degree of assimilation illusion would be smaller with large spatial separations than with small ones. However, contrary to predictions, the results indicated that with long contextual extents magnitude of assimilation illusion was either unrelated (Experiment I) or inversely related (Experiment V) to spatial separation.

Piagetian theory. From the present results Piagetian theory is faced with several difficulties. First the theory is faced with the problem of contrast with short contextual extents. The theory would require a major revision in order to account for this finding. In addition the theory has difficulty with the separation by length interaction and the effects of spatial separation. According to Piagetian theory degree of assimilation illusion is predicted to be inversely proportional to degree of separation. It is evident from Experiments I and V that this is not the case. In addition it would be expected from the theory that in Figures 12 and 17, which display the interaction between contextual length and spatial separation, with contextual length plotted on the abscissa, that the curves would not cross over one another, whereas in fact they do.

The theory also predicts some aspects of the findings. It correctly predicts the inverted U-shaped function between contextual length and degree of illusion. In addition the lack of contrast with long contextual extents is also consistent with the theory.

Assimilation theory. Assimilation theory also had mixed success in predicting the results. In general the theory correctly predicted the effects of position and the position by contextual length interaction, however, the theory predicted that the interaction between position and contextual length would be ordinal and not disordinal. To be more specific it was expected that larger assimilation illusions for the below position would exist across all values of contextual extents; however, for the longest contextual extents larger illusions were observed with the above position (Experiment III).

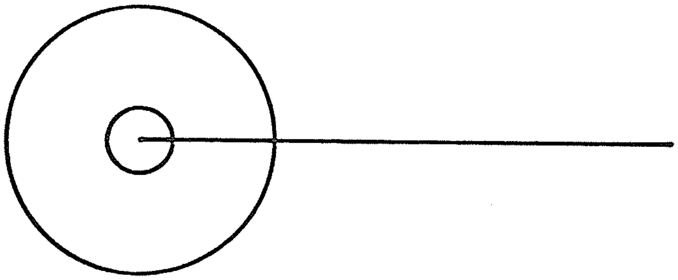
Of greatest difficulty for assimilation theory are the findings of contrast with short contextual extents and the general lack of contrast with long contextual extents. According to the theory as contextual extents increase in extent, the tips of the contextual line recede from the assimilation portion of the interactive field and enter into the contrast surround. In addition, as spatial separation increases the tips of the contextual extent should also move from the assimilation to the contrast portion of the interactive field. Therefore, from the theory it would be predicted that contrast would occur for displays which consist of long contextual extents and large spatial separations. Consider first the results for displays with long contextual extents. The findings from Experiment V indicate that if contrast is to be found with long contextual extents that it would be found with small separations and not large ones. The same observation also holds true for the observation of contrast with short contextual extents; namely, contrast is more likely to occur with small spatial separations than for large ones.

One way assimilation theory could be altered to account for contrast with short contextual extents and small spatial separations is through modification of the set of properties associated with interactive fields. In Figure 18 a test line and an interactive field positioned at the tip of the test line is displayed. The interactive field is divided into two areas, a small inner region and a larger outer portion. When the tips of the contextual line fall within the inner portion contrast occurs and when it falls in the outer portion assimilation occurs. To be consistent with the past interpretations of interactive fields it is postulated that the effectiveness of the contextual line in altering the test line diminishes as the distance between the tips of the contextual and test lines increases. With this modification the theory would explain the finding that degree of contrast is inversely related to spatial separation and that contrast occurs with short contextual extents.

Although this interpretation of interactive fields is plausible, the addition of the inner field requires that the status of the construct of interactive fields be reassessed. Does the interactive field consist of two or three separate areas? The third area is the outer contrast field suggested by Pressey and Wilson (1980). They argue that if the end point of a contextual extent lies in the outer area of the field that contrast will occur. Since contrast did not occur in the way suggested by Pressey and Wilson this interpretation of interactive fields is not correct. Therefore, to be consistent with the present findings it seems that interactive fields should be divided into two areas, an inner contrast field and an outer assimilation field.

An overview. The most important discovery, in the present series of

Figure 18: An example of the hypothesized interactive field. In the inner circle contrast is found and in the outer circle assimilation is found.



studies, is the observation of contrast for displays that consist of short contextual extents positioned close to the test extent. This finding is unexpected since neither past findings in the literature nor current theories suggest that contrast will occur for these parameters of displays. Future research should examine further the discovery to discern the range of contextual extents and spatial separation which induce contrast.

A second important finding involves the effect of spatial separation on degree of illusion. The results show that degree of illusion, both assimilation and contrast, diminishes with increased spatial separation. This finding is consistent with an interpretation of the effect of spatial separation which suggests that separation is involved with determination of degree but not necessarily type of illusion.

The other findings were consistent with the results of past researchers. As Brigell et. al. found, degree of assimilation illusion varied as an inverted U-shaped function of contextual extent. However, with increased spatial separation the degree of change in magnitude of assimilation illusion decreased when contextual extent varied. Furthermore, the results confirmed those of Pressey and Murray (1975) that position of contextual extent altered degree of assimilation illusion. Assimilation illusion was of greater magnitude, with contextual extents of moderate length, when the contextual line was positioned between test and response line then when it was positioned on the side of the test line opposite to that of the test line. However, with long contextual lengths larger assimilation illusions occurred with the context placed on the side of the test line opposite to that of the response line than when it was positioned between the test and response lines.

The present research does not resolve the issue of contrast with long contextual extents. For some illusions, such as the Delboeuf and the Titchener circles, contrast occurs readily with large contextual elements; yet, with the displays used in the present set of studies, contrast is generally not observed. Research, such as that performed in Experiment V, with qualitative variables could resolve this problem.

Footnoes

1. A log transformation was used since it provided a simpler model than non-transformed values.

Bibliography

Andrews, D.P. Error-correcting perceptual mechanisms. Quarterly Journal of Experimental Psychology, 1964, 16, 104-115.

Bates, M. A study of the Muller-Lyer illusion with special reference to paradoxical movement and the effects of attitude. American Journal of Psychology, 1923, 34, 46-72.

Bayer, C.A. & Pressey, A.W. Geometric illusions as a function of pigmentation of the Fundus oculi and target size. Psychonomic Science, 1972, 26, 77-79.

Benussi, V. Zur psychologie der Gestalterfassen. In Meinong, A. Untersuch Gegenstandstheorie, 1904, 303-448, Cited by Woodworth & Schlosberg, 1938.

Binet, A. La measure des illusions visuelles chez les enfants. Revue Philosophique, 1895, 40, 11-25.

Boring, E.G. Letter to editor. Scientific American, 1961, 204, 18-19.

Boring, E.G. Sensation and Perception in the History of Experimental Psychology. New York: Appleton-Century-Crofts, 1942.

Bridgeman, P. W. The Logic of Modern Physics. New York: Macmillan, 1927.

Brigell, M., Uhlarik, J., & Goldhorn, P. Contextual influences and illusions of extent. Journal of Experimental Psychology: Perception & Human Performance, 1977, 3, 105-118.

Brigner, W.L. Mathematical model for assimilation and contrast in perception of extent. Perceptual & Motor Skills, 1977, 45, 103-118.

Butchard, N. & Pressey, A.W. The effects of closing lines on the two forms of the Muller-Lyer illusion. Psychonomic Science, 1971, 23, 257-258.

Carr, H.A. An Introduction to Space Perception. New York: Longmans Green, 1935.

Christie, B.P. A contaminating factor in the measurement of geometric illusions. Psychonomic Science, 1969, 17, 69-70.

Clavadetscher, J.E. & Anderson, N.H. Comparative judgment: A test of two theories using the Baldwin figure., Journal of Experimental Psychology: Human Perception and Performance, 1977, 3, 119-135.

Coren, S. & Girgus, J.S. Seeing is Deceiving: The Psychology of Visual Illusions. Hillsdale, New Jersey: Lawrence Erlebaum Associates, 1978.

Coren, S. & Girgus, J.S. A comparison of five methods of measuring illusions. Behavioral Research Methods & Instrumentation, 1972, 4, 240-244.

Davies, T.N. & Spencer, J. An explanation for the Muller-Lyer illusion. Perceptual & Motor Skills, 1977, 45, 219-224.

Day, R.H. On the stereoscopic observation of geometric illusions. Perceptual & Motor Skills, 1961, 13, 247-258.

Day, R.H. The effects of repeated trials and prolonged fixation on error in the Muller-Lyer illusion. Psychological Monographes, 1962, 76, no. 14 (whole no. 533).

Dewar, R.E. Stimulus determinants of the Muller-Lyer illusion. Perceptual & Motor Skills, 1967, 24, 707-710.

Dixon, W.J. & Brown, M.B. BMDP Biomedical Computer Programs P SERIES 1979. Berkely: University of California Press, 1979.

Ebert, P.C. & Pollack, R.H. Magnitude of the Muller-Lyer illusion as a function of hue, saturation, and fundus pigmentation. Psychonomic Science, 1972, 26, 225-226.

Erlebacher, A. Sekuler, R. Explanation of the Muller-Lyer illusion: Confusion theory examined., Journal of Experimental Psychology, 1969, 80, 462-467.

Erlebacher, A. & Sekuler, R. The illusions of Muller-Lyer as a function of exposure duration. Unpublished manuscript.

Evans, C.R.& Marsden, R. P. A study of the effect of perfect retinal stabilization on some well-known visual illusions, using the after-image as a method in compensating for eye movements. British Journal of Physiological Optics, 1966, 23, 242-248.

Fellows, B.J. Reversal of the Muller-Lyer illusion with changes in the length of the inter-fins line. Quarterly Journal of Experimental Psychology, 1967, 19, 208-214.

Fellows, B.J. The reverse Muller- Lyer illusion and "enclosure". British Journal of Psychology, 1968, 59, 369-372.

Fellows, B.& Thorn, D.A test of Piaget′s theory explanation of the Muller-Lyer illusion. British Journal of Psychology, 1973, 64, 83-90.

Fisher, G.H. An experimental study of angular subtension. Quarterly Journal of Experimental Psychology, 1969, 60, 179-185.

Fraisse, P. L′integration temporelle des elements des illusions optico-geometriques et l′inversion de l′illusion de Muller- Lyer. L′Annee Psychogique, 1971, 53-72.

Gardner, R.L. & Long, R.I. Selective attention and the Muller-Lyer illusion. Psychological Record, 1961, 11, 317-320.

Georgeson, M.A. & Blakemore, C. Apparent depth and the Muller-Lyer illusion. Perception, 1973, 2, 225-234.

Girgus, J.S., Coren, S., & Agdern, M. The interrelationships between the Ebbinghaus and Delboeuf illusions. Journal of Experimental Psychology, 1972, 95, 453-455.

Green, D.M. & Swets, J. Signal Detection Theory and Psychophysics. New York: John Wiley, 1965.

Greene, R.T., Lawrence, R.B., & Godeck, C.L. The Ponzo illusion in stereoscopic space. Journal of Experimental Psychology, 1972, 95, 358-364.

Gregory, R.L. Eye and Brain, London: Weidenfeld & Nicolson, 1966.

Helson, H. Adaptation-Level Theory. New York: Harper & Row, 1964.

Heymans, G. Quantitative untersuchungen ueber das "optische paradoxen. Zeitschrift fur Psychologie, 1895, 9, 221-255.

Ikeda, H. & Obonai, T. Studies in figural after-effects (IV) The contast-confluence illusion of concentric circles and the figural after-effect-. Japanese Psychological Research, 1955, 2, 17-23.

Jaeger, T. Effects of changes in fin-length on apparent shaft-length and depth in the Muller-Lyer illusion. Perceptual and Motor Skills, 1975, 41, 79-84.

Johannsen, D.E. Early history of the perceptual illusion. Journal of the History of the Behavioral Sciences, 1971, 7, 127-140.

Keats, J.A. An application of the method of paired comparisons to the study of the Delboeuf illusion. Australian Journal of Psychology, 1964, 16, 169-174.

Keppel, G. Design and Analysis: A Researchers Handbook. Englewood Cliffs: Prentice-Hall Inc., 1973.

Kerlinger, F.N. & Pedhazur, E.J. Multiple Regression in Behavioral Research. New York: Holt, Rinehart & Winston, Inc., 1973.

Kunnapas, T.M. Influence of frame size on apparent length of a line. Journal of Experimental Psychology, 1955, 50, 168-170.

Lewis, E.O. Confluxion and contrast effects in the Muller Lyer illusion. British Journal of Psychology, 1909, 3, 21-41.

Massaro, D. & Anderson, N.H. Judgmental model of the Ebbinghaus illusion. Journal of Experimental Psychology, 1971, 89, 147-151.

Murkerji, N. Is "illusion" illusion? The Journal of General Psychology, 1957, 57, 209-212.

Obonai, T. Induction effects in illusions of extent. Journal of Experimental Psychology, 1954, 47, 57-60.

O'Halloran, W.J. & Weintraub, D.J. Delboeuf "illusion" of circle size induced via photo-flash generated afterimages. Perception and Psychophysics, 1977, 22, 171-176.

Ohwaki, S. On the destruction of geometrical illusions in stereoscopic observations. Tohoku Psychologica Folica, 1960, 19, 29-36. Cited by J.O. Robinson in the Psychology of Visual Illusion London: Hutchinson, 1972.

Oyama, T. Japanese studies on the so-called optical illusions. Psychologica, 1960, 3, 7-20.

Piaget, J. The Mechanisms of Perception. Translated by G.N. Seagrim, New York: Basic Books, 1969.

Pollack, R.H. Muller-Lyer illusion: Effect of age, lightness contrast, and hue. Science, 1970, 170, 93-95.

Pollack, R.H. Simultaneous and successive presentation of elements of the Muller-Lyer figure and chronological age. Perceptual & Motor Skills, 1964, 19, 303-310.

Pressey, A.W. A theory of the Muller-Lyer illusion. Perceptual & Motor Skills, 1967, 569-572.

Pressey, A.W. An extension of assimilation theory to illusions of size, area, and direction. Perception & Psychophysics, 1971, 9, 172-176.

Pressey, A.W. The assimilation theory of geometric illusions: An additional postulate. Perception & Psychophysics, 1972, 11, 28-30.

Pressey, A.W. Evidence for the role of attentive fields in the perception of illusion. Quarterly Journal of Experimental Psychology, 1974, 26, 464-471.

Pressey, A.W. & Bross, M. Assimilation theory and the reversed Muller-Lyer illusion. Perception, 1973, 2, 211-217.

Pressey, A.W., Butchard, N., & Scrivner, L. Assimilation theory and the Ponzo Illusion: Quantitative predictions. Canadian Journal of Psychology, 1971, 25, 486-497.

Pressey, A.W. & Di Lollo, V. Effects of distance between standard and comparison lines on the Muller-Lyer illusion. Perception & Psychophysics, 1978, 24, 415-419.

Pressey, A.W., Di Lollo, V., & Tait, R.W. Effects of gap size between shaft and fins and of angle of fins on the Muller-Lyer illusion. Perception, 1978, 6, 435-439.

Pressey, A.W. & Murray, R. Further developments in the assimilation theory of geometric illusions: The adjacency principle. Perception & Psychophysics, 1976, 19 536-544.

Pressey, A.W. & Wilson, A.E. Assimilation theory and the Baldwin illusion. The Italian Journal of Psychology, 1980.

Pressey, A.W. & Wilson, A.E. The hydra-headed Muller-Lyer effect: A theoretical puzzle, Perception & Psychophysics, 1977, 22, 392-394.

Pritchard, R.M. Visual illusions viewed as stabilized retinal images. Quarterly Journal of Experimental Psychology, 1958, 10, 77-81.

Restle, F. Assimilation predicted by adaptation-level theory with variable weights. In Cognitive Theory, vol. 2, ed. Castellan jr., N.J. & Restle, R.; Hillsdale, New Jersey: Lawrence Erlebaum Associates, 1978, 75-91.

Restle, F. & Decker, J. Size of the Muller-Lyer illusion as a function of its dimensions: Theory and data. Perception & Psychophysics, 1977, 21, 489-503 .

Restle, F. & Merryman, C.T. An adaptation-level theory account of a relative-size illusion. Psychonomic Science, 12, 1968, 229-230.

Riggs, L.A., Armington, J.C., & Ratliff, F. Motions of the retinal image during fixation. Journal of the Optical Society of America, 1954, 44, 315-321.

Robinson, J.O. The Psychology of Visual Illusion. London: Hutchinson and Co., 1972.

Schiller, P. & Wiener, M. Binocular and stereoscopic viewing of geometric illusions. Perceptual & Motor Skills, 1962, 15, 739-747.

Smith, W.G. & Sowton, S.C.M. Observations on spatial contrast and confluence in visual perception, British Journal of Psychology, 1907, 2, 196-219.

Springbett, B.M. Some stereoscopic phenomena and their implications. British Journal of Psychology, 1961, 52, 105-109.

Sweeney, O. Successive trials effects in the two forms of the Muller-Lyer illusion. Ph. D. Thesis, University of Manitoba, Winnipeg, Manitoba.

Titchener, E.B. Experimental Psychology; A manual of laboratory practice Vol. 1, part2, instructor's manual. London: Macmillan, 1918.

Uttal, W.R. The Psychobiology of Sensory Coding. New York: Harper & Row, 1973.

Walker, E.H. A mathematical theory of optical illusions and figural aftereffects. Perception & Psychophysics, 1973, 13, 467-486.

Warren, H. Dictionary of Psychology. Boston: Houghton Mifflin, 1934.

Warren, R.M. & Bashford, J.A. Muller-Lyer illusions: Their origins in processes facilitating object recognition. Perception, 1977, 6, 615-623.

Weintraub, D.J. & Walker, E.L. Perception. Belmount, California: Brooks/ Cole, Publishing Co., 1966.

Wickelgren, B.G. Brightness contrast and length perception in the Muller-Lyer illusion. Vision Research, 1965, 5, 141-150.

Wilson, A.E. The effects of repeated presentation of the Muller-Lyer as a function of two different psychophysical methods. B.A. (Hons.) Thesis, Mount Allison University, Sackville, New Brunswick, 1972.

Wilson, A.E. & Harper, D.W. The locus of maximum weighting within attentive fields: An empirical investigation. Quarterly Journal of Experimental Psychology, 1977, 29, 97-106.

Winer, B.J. Statistical Principles in Experimental Design. New York: McGraw-Hill, 1962.

Woodworth, R.S. & Schlosberg, H. Experimental Psychology. New York: Holt, Rinehart, & Winston, 1938.

Yanagisawa, N. Reversed illusion in the Muller-Lyer illusion. Japanese Journal of Psychology, 1939, 14, 321-326.

Zusne, L. Optical illusions: Output of Publications. Perceptual & Motor Skills, 1968, 27, 175-177.

Appendix A

Illusions of Extent: A Review

Chapter 1

Introduction

When the length of the three horizontal lines shown in Figure 1.1 are compared, the bottom line appears shorter than the middle line, which in turn seems shorter than the upper one. Measurement with a ruler, however, reveals that each are of equal physical length. The apparent difference in length among the lines reflect the essence of optical illusions; namely that context alters appearance.

This review is concerned with configurations similar to the ones shown in Figure 1.1. They all reflect illusions of extent. In this review historical background, parametric data, definitions, and theories of illusions are considered. In the first chapter interest in illusions and the definition of illusions are discussed. In the following chapter stimulus determinants of illusions are reviewed. Theories of illusions are analyzed in the final chapter.

Interest in Illusions

The occurrence of illusions have been known for centuries. Johannsen (1971), who reviewed their early history, noted that Aristotle was intrigued with illusions and today one bearing his name exists. Johannsen also pointed out that illusions were put to practical use during the Greek empire by architects and engineers who incorporated illusions in buildings to make them appear more aesthetically pleasing. The study of illusions thus began before psychology became recognized as a distinct discipline, and when it did become of age, illusions were one of the first problems studied. The study commenced with Oppel's

Figure 1.1: The top horizontal line appears longer than the middle line, which in turn appears longer than the bottom line. Each line is of equal physical length.

investigation of the filled-space illusion in 1855 (Robinson, 1972) and led to widespread experimentation and analysis of illusions.

Titchener (1918), who listed 12 theories of the Muller- Lyer configurations shown in Figure 1.1, believed the psychological atmosphere of the last half of the nineteenth century to be particularly conducive to the study of illusions. Zusne (1964), however, demonstrated that not only was this period of time conducive to their study since throughout the years articles on illusions have increased in proportion to the increase in the total number of articles published in psychology. The interest in illusions is likely to be maintained or enhanced as a result of the recent books The Psychology of Visual Illusion by J.O.Robinson and Perception is Deceiving by S.Coren and J.Girgus. The two publications provide a comprehensive survey of the literature and thus make theory and data on illusions more readily available.

Boring (1942),in his review on the history of illusions, suggested that the early interest stemmed from the belief that they represented instances of abnormal perception. The study of abnormal perception, it was thought, would provide insight in the way normal perception occurred. At the present time, however, illusions are thought to represent the occurrence of normal perceptual activity (Andrews, 1964; Gregory, 1966). Thus it is now believed that the study of illusions provides a means of studying normal perceptual activity.

Definition of Illusions

Before proceeding, the term illusion will be defined. The issue becomes important, as we shall see, when magnitude and direction of illusions are considered. Presently, two viewpoints are maintained.

One assumes that since perception should be veridical, any deviation from veridicality represents illusion. This point of view is maintained in a dictionary of psychological terms (Warren, 1934), in a recent source book on illusions (Robinson, 1972), and is evident in the methodology used by well known researchers (e.g. Coren & Girgus, 1972; Gregory, 1966). On this viewpoint, if a 50 mm line embedded within a configuration is judged to be unequal in length to another 50 mm line, the configuration is judged to be illusory. The definition of illusion is thus based upon the difference in physical extent between two magnitudes.

Although a definition of illusion in terms of differences between physical magnitudes may be superficially appealing, it fails to take judgmental errors into account (Murkergi, 1957). In the present day terminology of the theory of signal detectability (Green & Swets, 1965), judgmental errors are classified as response bias.

The second viewpoint compensates for response bias. This definition, although not articulated explicitly in the literature, is implicit from the operations used to define illusions (e.g. Brigell, Uhlarik, & Goldhorn, 1977; Butchard & Pressey, 1971; Restle & Decker, 1977). The operations define illusion as the difference between responses produced to configurations with and without a context.

The reader will no doubt pose the question, "What is a context free configuration?", since, as Boring (1942) noted, all experience occurs in a context. However, context free configurations may be defined operationally (Bridgeman, 1927) as ones consisting of only judged magnitudes. A display consisting of only the shaft in the Muller-Lyer configuration is an example of a context free display. Configurations of this type are termed control displays.

Although the amount of effort expended on definitions may be questioned, this is an important issue which requires further discussion to be fully appreciated. Below where the issue is presented in greater detail, logical and empirical arguments supporting the second definition are presented. It is this author's belief that this definition is to be preferred.

Logical support. If we accept the definition which takes into account response bias how do we know that part of the illusion is not still present when we use displays to control for response bias? Fisher (1969) provided a sound logical reply to this query. Often it was believed that visual defects of painters could be known through their works of art. For example, it was widely thought that El Greco was inflicted with a visual defect since his paintings contained figures orientated obliquely. This belief was based on the assumption of a one-to-one correspondence between painting and perception. However, as Fisher noted, if El Greco had a visual defect and if he painted according to his visual perception, no distortion of scenes would be evident since both scenes and paintings would be distorted an equal amount. Consequently, if Fisher's assumptions are correct, any attempt to reproduce faithfully a given item should, with everything equal, result in equivalence between judged and reproduced items.

It should also be noted that the problem of response bias has been acknowledged and incorporated within a variety of areas within perception (Green & Swets, 1965). Given that judgmental processes occur in the production of responses in illusion tasks, it seems mandatory that their effects should be controlled.

The Role of Response Bias

Measurement. Response bias is measured by obtaining responses to control figures and then calculating the difference between reproduced and judged extents. For example, to obtain a measurement of bias in responses to the Muller-Lyer configuration, judgments of control figures, which consist only of the shaft, would be obtained. Deviation of judgments from the physical length of the shaft would provide measures of response bias, since according to Fisher′s argument, if judgments of length were based only on visual perception, responses and shaft would be of identical extents.

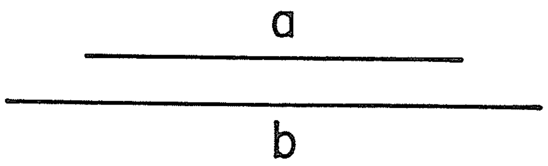
Although response bias has received little systematic study, it is known that responses can deviate systematically from the objective length of control magnitudes. Brigell *et al* (1977), for example, found the average length of control responses deviated approximately 10% in length from control lines. Furthermore, in unpublished work, Sweeney (1973) and Wilson (1972) discovered that response bias varied systematically with practice.

Reliability and association with responses to illusion configurations. Although responses to control configurations are known to vary with practice and to differ in length from physical extents, little is known about their reliability and their association with responses to illusion configurations. In control displays if response bias is responsible for divergence of responses from judged extent, and if subjects display systematically response bias, responses to control configurations would be positively correlated. Furthermore, if response bias is reliable and if it plays a role in responses to illusion configurations, then responses between control and illusion configurations would be associated.

To further knowledge about responses to control configurations and to examine the reliability of response bias and its association with responses made to illusion configurations, data from studies conducted by Pressey and Murray (1976) and by Pressey and Wilson (1977) were reanalyzed. In the study performed by Pressey and Murray, observers were tested on variants of the parallel line configuration shown in Figure 1.2. With this illusion apparent expansion of the test line occurs. One group of subjects were shown displays with the contextual line placed between test and response lines and a second group were shown displays with the test line placed between contextual and test lines. Each observer was tested on two sequences of one control and nine illusion configurations. Within sequences, observers produced two consecutive responses to each configuration. The response was drawing a line which appeared equal in length to the test line. One response originated 100 mm directly below and 8 mm to the left of the left point of the test line and the second response started 100 mm directly below and 8 mm to the right of the left point of the test line. Left and right positions were counterbalanced within and between observers.

For each subject, length of control responses was measured and averaged within sequences to provide two measures of responses to control configurations. For each group , responses between sequences were subjected to a Pearson product-moment correlational analysis. This analysis indicated that responses between sequences were reliably associated. For one group, the correlation coefficient, (_r_), was .46 and for the second an _r_ of .57 was found. Since 34 degrees of freedom (_df_) were associated with each calculation, the probability that the

Figure 1.2: The parallel line configuration used by Pressey and Murray (1976). The contextual line (b) increases the apparent length of the test line (a).


a
b

associations occurred by chance were smaller than .002 and .001 for the first and second calculations, respectively. Thus, subjects were consistent in producing their length of response.

The next analysis tested the prediction; if response bias influences responses to illusion configurations, and if response bias is reliable, then responses to control and illusion configurations will be positively correlated. An initial test of this prediction used data from the experiment performed by Pressey and Murray (1976). Responses to variants of the parallel line configuration, with closest proximity of test and contextual line, were used in the analysis. Responses within each of two sequences were then averaged to provide two measures of responses to illusion configurations per observer. For each group of observers one correlation coefficient per sequence was calculated between responses to illusion and control configurations.

The value of the four _r's_ ranged from .407 to .660. Since 34 _df_ were associated with each calculation, the probability that the associations occurred by chance ranged from .007 to .001. Thus, responses made to illusion and control configurations were reliably associated and furthermore, since the obtained _r's_ were positive, the results also demonstrated a direct relationship between responses made to illusion and control configurations. Thus the longer the response made to control displays the longer the response made to illusion configurations.

Since the variant of the parallel line configuration used by Pressey and Murray (1976) produces apparent expansion of the test line, it is of interest to know if responses to configurations producing apparent shrinkage are also associated reliably with responses to control figures. Furthermore, it is of interest to discover if the association found between responses to the control and parallel line illusion appears between responses to other illusion and control configurations. If reliable associations are found in these instances, it would seem that response bias may have systematic effects on a variety of responses to illusion configurations.

Data from an experiment performed by Pressey and Wilson (1977) were reanalyzed to examine these points of interest. In this study responses to the ingoing and outgoing Muller-Lyer configurations, as well as to control figures, were collected with procedures analogous to those described above. In the reanalysis of the data, two product-moment correlation coefficients were calculated; one between responses to control and ingoing displays and one between control and outgoing configurations. Each analysis indicated that reliable associations occurred between responses to control and illusion configurations. Between responses to control and ingoing configurations and between responses to control and outgoing configurations the obtained *r's* were .68 and .57, respectively. With 19 *df*, the probability that these associations could have occurred by chance were smaller than .001 and .01 respectively.

At this time it may be profitable to consider the import of these findings. In the first analysis, a reliable association between responses to control figures was found. Thus, observers were consistent in their responses to control figures. Furthermore, if responses of different length produced to control figures reflected different levels of response bias then the amount of response bias displayed by subjects was consistent.

In the second set of analyses, reliable associations between responses to various illusion and control configurations were discovered. If responses bias was reflected by responses to control lines, responses to illusion configurations were affected systematically by response bias. Thus responses to illusion configurations contained a systematic confounding variable when response bias was not controlled. If a subject had a tendency to produce long lines, long lines were produced or if a subject had a tendency to produce short lines, short lines were produced.

Statistically, the occurrence of response bias and its reliable association with responses to illusion configurations means spurious correlations will occur among responses to illusion configurations. When response bias is not controlled, spurious positive correlations among either illusions of expansion or illusions of shrinkage will occur. In contrast, negative correlations between illusions of expansion and shrinkage will be observed. This pattern of correlation coefficients reflects the effect of adding systematic variance to responses made to the different classes of configurations.

The preceding pattern of correlational results was obtained by Christie (1969). He found positive correlations among illusions of expansion and a negative correlation between the ingoing and outgoing Muller-Lyer illusions. However, as noted above, response bias, which was not controlled in his study, could have produced this pattern of results. His findings led Christie to comment on the possibility of an artifact in the measurement of illusion. For Christie and the present author it seems odd for a process or mechanism to produce a large illusion in one instance, but a small one in a second.

To arrive at a true measure of association between responses produced to configurations, response bias must be controlled. Partial correlation (Kerlinger & Pedhazur, 1973) provides one way to accomplish this. The underlying basis to this technique is first to remove the variance associated with control figures from responses made to illusion figures to provide residual scores and then correlate residual scores.

Since subjects in the study performed by Pressey and Wilson responded to control and to two illusion configurations, the study met the requirements for a partial correlation analysis. Residual scores, after the effects of control responses were removed, were not found to be reliably associated ($\underline{r}$=0.18, df=18, p>.10). Thus this analyses failed to demonstrate a reliable association between the two forms of the illusion after response bias is controlled. That is, when the contribution of response bias is removed, a reliable association between the two forms of the Muller-Lyer illusion is no longer demonstrable.

Summary and conclusions. A definition of illusion based upon the difference in the magnitude of response produced between configurations with and without a context was supported. The discussion provided logical and empirical backing for this position. First, the argument of Fisher (1969) provided logical support. Then empirical support was produced through demonstration of reliability of control scores and association between responses produced to illusion and control configurations. Response bias, a hypothetical construct, was linked closely with empirical data and logical arguments.

CHAPTER 2

Stimulus Parameters

Much of the illusion literature is comprised of variables affecting the direction and magnitude of illusion. This literature divides into two classes; namely, viewing conditons and components of displays. Manipulation of viewing conditions are important in evaluating theories based on eye-movements and explanations predicting the level of processing producing illusions. Alteration of display variables comprising the illusion configurations provide the data base to develop and evaluate theories.

For ease of presentation studies manipulating components of displays will be reviewed before those altering viewing condions. Since the Muller-Lyer illusion has received the most attention in the literature, research with the Muller-Lyer configuration will be emphasized more than research with other configurations. However, results with other configurations will be included when results with the Muller-Lyer are not available.

The Muller-Lyer. In its usual form the Muller-Lyer consists of a shaft with fins attached at each end. Generally when the fins point toward each other (Figure 1.1c) the shaft appears elongated (expansion) and when the fins point away from each other (Figure 1.1a) the shaft seems shortened (shrinkage). However, neither fins *per se*, (Robinson, 1972) nor the direction that the fins point (Pressey & Bross, 1973) determine the direction of illusion. Generally the most important condition concerns distances between the fins. If the distance is greater than the shaft, expansion occurs; if it is shorter, shrinkage results.

Although the Muller-Lyer and other illusions are simple configurations the variety of manipulations they undergo is remarkable. Components of displays can be increased in quantity, changed in size, coloured differently, or presented at different times. To organize these alterations they will be considered in four distinct categories; namely, spatial, colour, quantity, and temporal. Within these the majority of manipulations which alter components of display can be included.

Angle, length of fin, gap, depth, position of contex, and size of figure comprise the spatial characteristics to be considered. Angle, length of fin, gap, and their interactions are discussed together since they reflect two underlying spatial characteristics; namely, framing ratio (the ratio of contextual to test extents) and separation between contours. In the next section the discussion will focus on the effects of the third spatial dimension (depth). The following section considers the effect of position of context. As will be demonstrated below, position plays an important role in theory construction. The last variable to be considered is size. It appears that size has relatively greater influence on illusions of expansion than those of shrinkage.

Spatial Characteristics

Angle, fin length, and gap. Lewis (1909), in a factorially designed study, varied the length of fins between 5 and 35 mm and angle between fins from 20° to 180°. He found that as angle increased, magnitude of illusion decreased. Results from a variety of experiments (Coren & Girgus, 1972; Dewar, 1967; Erlebacher & Sekuler, 1969; Hymans, 1895; Davies & Spencer, 1977) generally concurred with this finding.

Lewis (1909) also found that alteration in length of fins did not have a simple effect on illusion. Increasing length initially increased and then decreased illusion. This nonmonotonic function between illusion and length has been replicated by other researchers (Brigell et al., 1977; Hymans, 1895; Jaeger, 1975; Restle & Decker, 1977).

Since Lewis (1909) varied angle and length factorially, he was able to study their interaction. He found that size of angle altered the fin length which produced maximum illusion. A shorter length was required to produce the largest illusion for sharp angles than for dull angles.

Oyama's (1960) report, on the findings of Ihara and Kideo (1934) and of Yanagisawa (1939), that insertion of a gap between the fins and shaft produced apparent expansion of the line between ingoing fins sparked several recent studies. Fellows (1967) confirmed the report and indicated that when the shaft was equal in length to one half of the distance between the apicies maximum reversal of illusion occurred. Two later studies indicated that the gap which produced reversal and peak expansion illusion depended upon configurational properties. Pressey and Bross (1973) found that a smaller gap was required to produce peak expansion illusion and reversal with short fins than with long fins and the findings of Pressey, Di Lollo, and Tait (1977) demonstrated that the smaller the angle the larger the gap required to produce reversal and peak illusion.

Framing ratio. Two underlying spatial relationships; namely, ratio of contextual to shaft extents (framing ratio) and the distance between fins and shaft (separation between contours) are involved in the effects of angle, length, and gap. As an approximation, the horizontal distance between the tips of the fins is used to represent contextual extent.

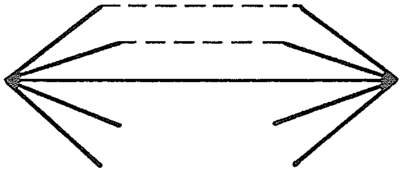
This measure is termed the intertip distance and is abbreviated as ITD (Erlebacher & Sekuler, 1969). As shown in Figure 2.1, altering angle, length, and gap changes the difference in extent between shaft and ITD. With length constant and no gap, decreasing the angle increases the difference. When angle is constant and when there is no gap, increasing length also increases the difference. For the ingoing configuration, increasing gap increases ITD when angle and length remain constant. Thus when ITD is initially shorter than the shaft, an increase in ITD reduces the difference in length between ITD and shaft extent but when ITD becomes longer than the extent of the shaft, increases in gap results in an increase in the difference.

If apparent shrinkage and elongation of shafts depend on ITD's shorter or longer, respectively, than extent of shafts, smaller gaps would be required to produce reversal of shrinkage illusions for smaller angles and shorter fins since as Figure 2.2 shows, ITD becomes longer than shafts for these configurations with smaller gaps. This hypothesis predicts correctly the direction of trends concerning the size of gap required to produce reversal in the studies of Pressey and Bross (1973) and Pressey et al. (1977).

Although the difference in extent between ITD and shaft is suggested to be the most important spatial relationship in producing illusion (Erlebacher & Sekuler, 1969; Fellows & Thorn, 1973; Pressey, 1972), Brigell _et al._, (1977) present evidence that the ratio of ITD to shaft extent is more important. They find that when this ratio becomes greater than 1:1, magnitude of illusion increases initially up to a ratio of 1.75:1 and then decreases, regardless of shaft extent.

If the ratio of ITD to shaft extent which produces peak illusion is

Figure 2.1: Increase in angle, length of fins, or gap increases ITD. ITD is represented by the dashed lines.



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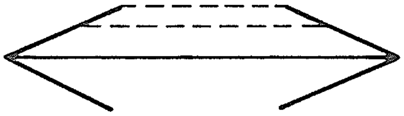

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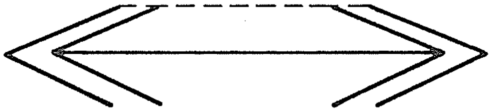

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invariant, or varies little, then the interaction between angle and fin length is easily understood. On making this assumption, it is predicted that for the outgoing configuration, since ITD increases at a faster rate for sharper angles when fin length increases, a shorter length is required to produce peak illusion. If the same assumption is made for the ingoing configuration, the same prediction is also made for it. The findings in the literature correspond to these predictions.

Given the assumptions made above, the findings of the effect of angle and fin length on the size of gap producing peak expansion of the shaft between ingoing fins are also explained. Configurations with dull angles and short fins would meet the critical ratio with smaller gaps than those with sharp angles and long fins since ITD is greater initially for these configurations.

It is reasonable to assume that considerable portions of the literature on alteration of angle could also be explained by the assumptions made above. For outgoing Muller-Lyer configurations with short and moderately long fins, decreasing the angle (that is, making the angle sharper) approaches the ratio which produces peak illusion.

Several questions are raised by the ease the manipulations discussed in this section fit into the function which relates magnitude of illusion to framing ratio. One question concerns the generality of the inverted U-shaped function. For other configurations does magnitude of illusion increase initially and then decrease as the framing ratio diverges from unity? The answer is an unqualified yes. Similar findings, when ITD is replaced with an analogous measure, are obtained for the Baldwin (Brigell, _et al._, 1977; Clavadetscher & Anderson, 1977), Delboeuf (Keats, 1964; Oyama, 1960), divided line (Brigell et al., 1977;

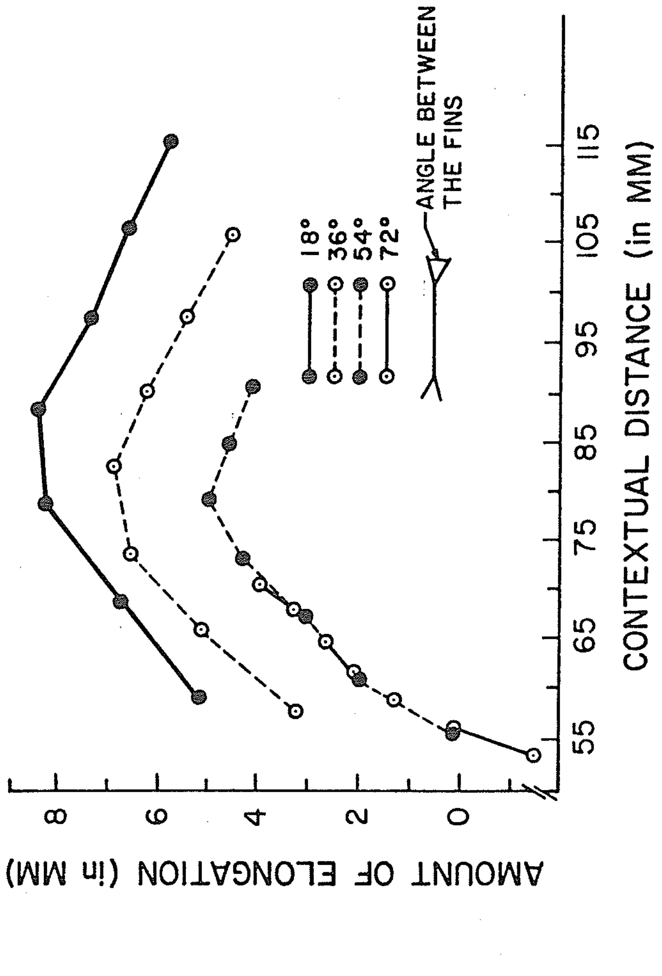
Lewis, 1909; Smith & Sowton, 1907), and parallel lines (Smith & Sowton, 1907) configurations.

A second question involves expansion and shrinkage of judged extent. Does expansion and shrinkage of judged extent occur invariably for framing ratios greater and smaller, respectively, than 1:1? Until now the assumption has been made that this is the case. However, it is widely known that when the outer circle in the Delboeuf configuration is sufficiently larger than the test circle, the inner circle appears diminished in magnitude (e.g. Keats, 1964). Thus apparent expansion of judged magnitudes does not necessarily occur with framing ratios greater than 1:1.

The two types of trends concerning the direction of illusion are termed assimilation and contrast (Woodworth & Schloesberg, 1938). When the difference in magnitude between test and contextual magnitudes is reduced perceptually the illusion is termed one of assimilation. For example, if the difference in extent between the shaft and the tips of the fins, in the expansion form of the Muller-Lyer, appears shorten the illusion is one of assimilation. On the other hand, if the difference is enhanced perceptually the illusion is one of contrast.

A third question concerns the framing ratio producing the largest illusion. Does the largest illusion occur invariably with a given framing ratio when framing ratio is varied? Findings with the Muller-Lyer configuration (Lewis, 1909), indicate that peak illusion depends upon size of angle. As shown in Figure 2.2, peak illusions occur with smaller ratios for dull angles than for sharp angles. Thus, when framing ratio is varied concomitantly with other variables, the framing ratio producing peak illusion is not invariant.

Figure 2.2: Apparent increase in shaft length as a function of contextual extent. Data are from Lewis (1909).


AMOUNT OF ELONGATION (in MM)
0
2
4
6
8
CONTEXTUAL DISTANCE (in MM)
55
65
75
85
95
105
115
18°
36°
54°
72°
ANGLE BETWEEN THE FINS

There is one final question that should be raised at this point, and this concerns whether or not some other variable is responsible for the nonmonotonic trend which is found by Brigell _et. al._. With an H shaped configuration, illusion varies as an inverted U-shaped function of fin length (Restle and Decker, 1977). Thus the function is very similar to those of Brigell _et. al._ but framing ratio remains constant at 1:1. Since contextual extent and the physical size of the context covary in the studies of Brigell _et. al._, it is plausible that the physical size of the context and not contextual extent is responsible for the framing ratio function. However, in light of some findings of Smith and Sowton (1909), this does not seem likely. Their results indicate that very similar functional relationships occur between degree of illusion and alteration of contextual extent in divided line and parallel lines displays. Since the physical extent of the context is so different in those configurations, contextual extent must produce the inverted U-shaped function. Hence it appears likely that under certain conditions both the physical size of the context and contextual extent produce nonmonotonic trends.

Separation. As mentioned earlier, separation between contours is a second underlying variable involved in the effects discussed in this section. Generally, it is argued that if separation increases then degree of illusion decreases. There are two ways that separation has been measured. One measures separation as the linear distance (LD) between tips of shaft and fins (Pressey & Murray, 1976) and the second uses the perpendicular distance (PD) between tip of fin and shaft (Brigner, 1977; Erlebacher & Sekuler, 1969; Fellows & Thorn, 1973).

Pressey and Murray (1976) provided direct evidence for the effects of separation. They varied PD between test and contextual lines in the parallel lines configuration. They found decreased magnitude of illusion with increased separation.

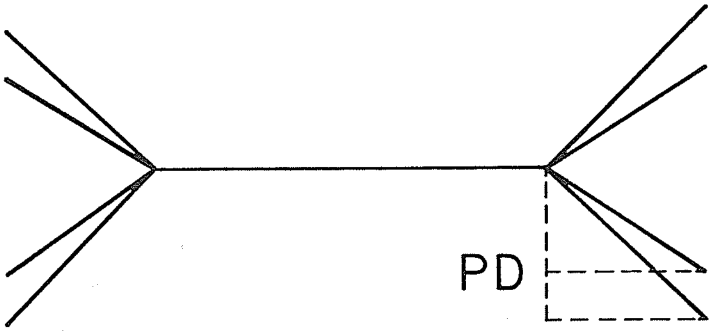
The effect of angle on separation is shown in Figure 2.3. When angle increases, there is an increase in PD. The concomitant change in separation with increasing angle may be responsible for an effect discussed earlier: for dull angles a smaller framing ratio produces peak illusion.

Further on, when theories of illusions are discussed, we will find that framing ratio (or analogous variables such as contextual extent) and separation weigh heavily in theories concerned with mathematical models of illusion. A major goal for these theories is to specify the way these two variables operate.

Apparent depth. Visual space may be described in three dimensions; namely, height, width, and depth. To this point we have discussed manipulations performed on two dimensions of space; namely, either width or height which were varied either directly or indirectly. However, manipulations need not be restricted to these two dimensions since either three dimensional configurations or two dimensional configurations presented with suitable apparatus can be used to study the role of depth in illusion. Most studies which examine the role of depth are concerned more with apparent depth than with physical depth because apparent depth has greater theoretical importance. Therefore, in this section apparent depth will be the focus of attention.

Georgeson and Blakemore (1973) varied with a stereoscope the apparent tilt of fins. They found decreased degree of illusion when the fins were tilted either towards or away from observers.

Figure 2.3: Increasing angle increases separation (PD).


PD

Greene, Lawson, and Godeck (1972) also demonstrated the influence of the third dimension on illusion. They altered stereoscopically the apparent depth of vertical lines in Ponzo and control configurations similar to those displayed in Figure 2.4 and had observers rate the apparent length of the vertical lines. Their results indicated that degree of illusion varied as a function of apparent depth and of position of lines. For lines closest to the apex of the wedge, maximum illusion (expansion) occurred when it appeared slightly behind the wedge. For the second line, maximum illusion (shrinkage) resulted when it seemed furthest behind the wedge.

Demonstration that the third dimension influences illusion introduces complexity in understanding spatial influences on illusion. Can effects produced by apparent depth be understood by the same relationships used to explain two dimensional configurations or do we need to develop spatial relationships exclusive to the third dimension to understand the influence of depth? Research to answer this question has yet to be performed.

Position of context. With the development of the assimilation theory of geometric illusions (Pressey, 1967; 1971; Pressey & Murray, 1976) the relative position of context and comparison line became theoretically important. This variable was studied in two experiments (Pressey, 1974; Pressey & Murray, 1976) with configurations asymmetrical above and below the shaft. Pressey (1974) found that with the context, in configurations similar to those depicted in Figure 2.5, placed on the same side of the shafts as the comparison line, larger illusions occurred than when it was placed on the opposite side. Similar findings were obtained by Pressey and Murray (1976). They found that, with the parallel line

Figure 2.4: An example of the Ponzo display. Control figures consist of the two parallel lines.

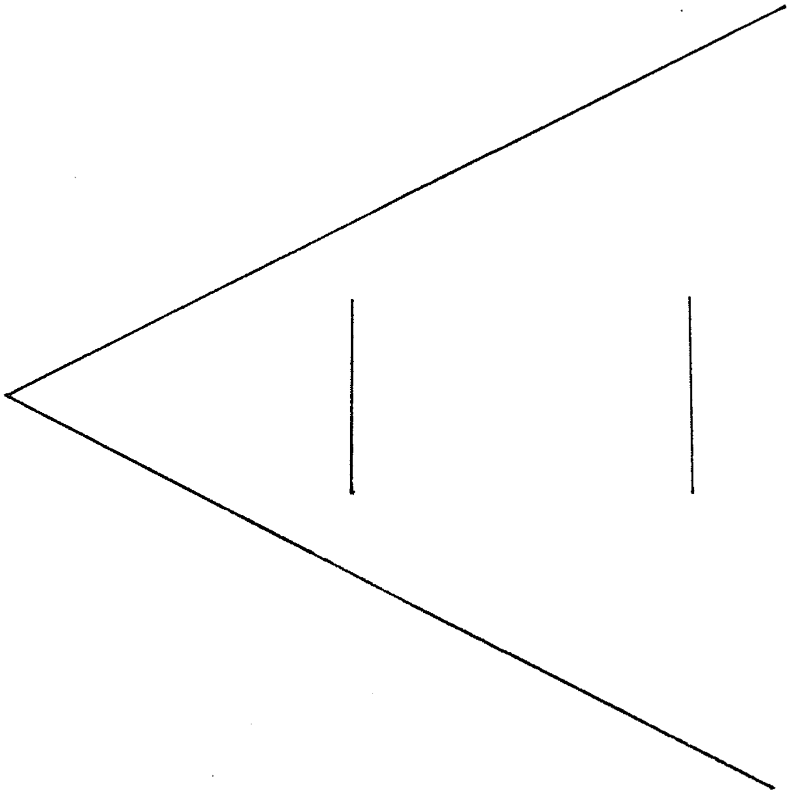
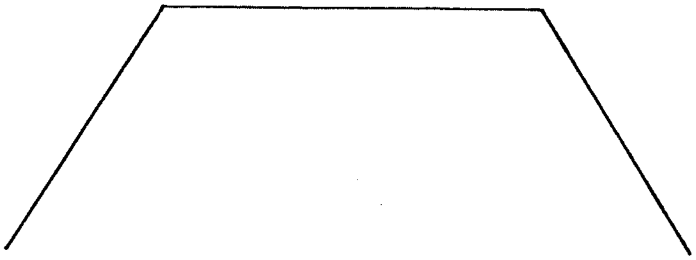


Figure 2.5: A configuration similar to the one used by Pressey (1974).



configuration, larger illusions occurred when contextual and response lines were placed on the same side of the test line than when they were on opposite sides.

Although position does have considerable influence on illusion, little emphasis has been directed toward explaining how it alters illusion. At the present time Pressey (1974) has been the only theorist to explain how it operates. He theorized that its influence may result from the way attention is distributed.

Size of configuration. To study the effects of size of configurations the relative lengths of fins and shaft are kept constant while their absolute lengths are altered. Then proportional illusions, i.e. degree of illusion relative to shaft length, are compared. The question of importance is whether or not proportional illusion changes in magnitude when absolute size of configurations vary. Findings obtained by Bayer and Pressey (1972) indicated that proportional illusion declined for the outgoing configuration but remained about constant for the ingoing configuration when absolute size increased.

Bayer and Pressey noted that their findings seemed to clarify results obtained by Binet (1895) and by Heymans (1895) who found, when they measured the ingoing configuration with the outgoing (or vice versa), that degree of illusion diminished with increased size. Bayer and Pressey (1972) argued that, if they extrapolated from their own findings it would seem likely the decrease found previously resulted from a decrease in the illusion produced by the outgoing configuration and not from a decrease produced by the ingoing configuration.

Colour

Colour consists of three attributes associated with visible light;

namely, brightness, hue, and saturation (Weintraub & Walker, 1966). Brightness correlates approximately with the amount of energy in light while hue and saturation corresponds to wavelengths of electromagnetic energy emitted from light sources. Various hues correspond to different wave lengths: for example, wave lengths of 420 and 660 nm produce sensations of blue and red respectively. Saturation, which refers to the quantity of white light present in light, influences hue. Thus adding white light to red produces pink light.

Hue and saturation. Relatively little research has focussed on the effects of hue and saturation on illusion. Mukerji (1957) found that varying the hue of fins altered apparent length of dark shafts. Red fins produced a larger illusion than green fins but not as large as the one produced by dark fins. Although it may appear from this study that hue influenced illusion, the results were ambiguous since the association between hue and brightness was not controlled (Wickelgren, 1965). Thus Mukerje's study may have demonstrated the effects of brightness rather than hue.

Pollack (1970), who did control for the association between hue and brightness, presented more conclusive evidence for demonstrating that hue influences illusion. He found the rank order of the hues which produced the largest outgoing illusion was red, blue, yellow, and green.

In a subsequent experiment, Ebert and Pollack (1972) discovered that level of saturation changed the rank order of hues which produced larger illusions. With relatively unsaturated configurations, the order was red, blue, and yellow, but for highly saturated configurations the rank order was blue, yellow, and red.

Brightness. Brightness can be varied among three components of displays; namely, shaft, fins, and background. The relative brightness of configurational components to background is termed brightness contrast. With an increase in the difference between the relative brightness of background to configurational components the amount of brightness contrast increases. Thus increasing the brightness of one component changes not only brightness but brightness contrast as well.

Two studies (Bates, 1923; Benussi, 1904; cited by Woodworth & Schloesberg, 1938), when considered collectively, obtained results which indicated that brightness contrast was more important than brightness in alteration of illusion. Benussi, who used black backgrounds, discovered that relative to grey shafts white shafts decreased illusion. Furthermore he found white fins produced relatively larger illusions than grey fins. Bates displayed configurations on white backgrounds and found that the darker the fins the larger the illusion. Thus both studies found that the greater the brightness contrast produced between fins and background the greater the illusion.

Wickelgren (1965) confirmed that brightness contrast was more important than brightness in alteration of illusion. Her results indicated that magnitude of illusion was inversely related to brightness contrast between shaft and background but directly related to brightness contrast between fins and background. On the basis of her findings Wickelgren hypothesized that magnitude of illusion varied as a function of the relative brightness contrast of fins and shaft to background. Although this hypothesis predicted correctly the findings discussed above, it failed to predict some additional findings she obtained. In particular, the hypothesis predicted that magnitude of illusion would remain constant as the absolute brightness contrast of shaft and fins to background varied. Wickelgren found, however, that for the ingoing figure, grey configurations on white backgrounds induced larger illusions than black configurations on the same background, and that, for the outgoing Muller-Lyer, larger illusions occurred for black configurations than grey ones on white backgrounds. Thus absolute brightness contrast, and possibly relative brightness contrast, alters illusion.

<u>The Effects of Time</u>

<u>Temporal gap.</u> Time has a curious effect on illusions. Under certain conditions insertion of a temporal delay between presentation of fins and shaft has the effect of reversing the direction of illusion. Pollack (1964), with the outgoing configuration, presented separately for 500 msec each first the fins, then a background, and finally the shaft. He found an illusion of contrast instead of one of assimilation. Thus introduction of a temporal gap between presentation of fins and shaft changed the type of illusion from one of assimilation to one of contrast.

Fraisse (1971), who required observers to compare length of shafts between ingoing and outgoing fins, clarified some of the effects of time. He found reversal occurred only if the fins preceded the shaft. Presentation of the fins after the shaft merely reduced the degree of illusion. Fraisse also found that the duration fins were displayed and the duration of the temporal gap together determined if the illusion would be reversed. With total durations of less than 180 msec, the direction of illusion found with simultaneous viewing (assimilation) occurred, but with longer durations reversal (contrast) was produced.

Ikeda and Obonai (1955), with the Delboeuf configuration, performed one of the most extensive studies on the effects of time on illusion.

They varied diameter of contextual circle and delay between onset of contextual and test circles. Delays and diameter ranged from 0 to 1000 msec and from 10 to 80 mm, respectively. The test circle, which was 30 mm in diameter, and the contextual circles were each presented for 500 msec. Thus with these values of delay and size of configurations, Ikeda and Obonai were able to compare the effects of delay on the psychophysical function relating magnitude of illusion to diameter of contextual circle.

The results from this study were as follows. With delays of 0 msec (simultaneous viewing) the typical inverted U-shaped function between magnitude of illusion and diameter of contextual circle occurred. Maximum underestimation and overestimation was found with diameters of 20 and 40 mm respectively. Furthermore, with the 80 mm diameter contexual circle the test circle appeared decreased in magnitude. Thus this contextual circle produced contrast. When the delay was increased from 0 to 100 msec magnitude of illusion decreased for all conditions except for the one which produced contrast. For this condition the amount of illusion was enhanced. With increased delays of 200 and 300 msec the direction of illusion began to reverse. Peak reversal occurred with a delay of 600 msec. With this delay, the psychophysical function between magnitude of illusion and size of contextual circle was virtually a mirror image to the one found with simultaneous viewing. The one exception was the illusion found with the contextual circle which produced contrast. The amount of contrast was substantially enhanced.

The results of Ikeda and Obonai are important in several respects. First, since reversal commences with a 200 msec delay, temporal separation between contextual and test magnitudes is not a necessary condition in determining reversal of illusion, because with this delay contextual and test circles overlap in time. Thus it is merely the duration between onset of components which determines reversal. Secondly, the results with the 80 mm diameter contextual circle are important because they illustrate the effects of time on contrast. Time has the effect of enhancing the amount of contrast. Thus, small illusions of contrast can be enhanced with insertion of temporal delays between onset of contextual and test circles.

Duration of exposure. Time influences illusion in one other way. Varying the duration configurations are presented alters magnitude of illusion. Piaget (1969) presented configurations tachistoscopically and varied exposure from .02 sec to .50 sec. Relative to unlimited viewing time, short exposures resulted in larger ingoing and outgoing illusions. However, when duration increased between .02 and .50 sec larger outgoing but smaller ingoing illusions resulted.

In an apparently unpublished experiment, Sekuler and Erlebacher replicated Piaget's study and included a control condition. In this control condition, observers judged the length of a configuration which did not contain fins. They found, as Piaget had, that the shaft between ingoing fins increased in length with exposures of increased duration but unlike the results from the study conducted by Piaget, the length of the shaft between outgoing fins remained constant with changes in duration. The results from the control condition also provided important data. They found that the shaft increased in length with increased duration. Furthermore, they found that the rate of increase in apparent length for the shaft between ingoing fins, as a function of exposure

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numbering

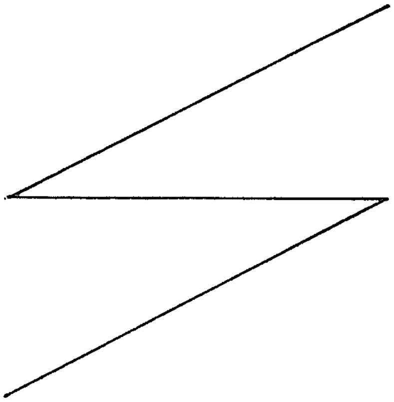
duration, was identical to the rate of increase for the shaft in the control condition. Thus after consideration of control data, Sekuler and Erlebacher suggested that the ingoing illusion remained constant with changed exposure duration but that the outgoing configuration decreased with increased duration.

Quantity of Contextual Components

In this section the effects of varying quantity of contextual components are considered. Quantity can be altered in two ways; namely, fins can either be added to or subtracted from the basic configuration. Fins are deleted for experimental and practical reasons. Experimentally, deletion allows one to determine whether the illusion persists with impoverished configurations or whether it occurs only with entire configurations. The consensus is that removal of fins does not eradicate or change the direction of illusion (Oyama, 1960; Robinson, 1972; Warren & Bashford, 1977), but does reduce its magnitude (Warren & Bashford, 1977). Warren and Bashford (1977) also report that removal of one-half a fin produces a smaller decrement in illusion than the removal of two components. Furthermore, additional results of these researchers appear to indicate that removal of components produces a larger decrement in illusion for the outgoing configuration than for the ingoing configuration.

Fins are also deleted because of a practical problem. Increasing the length of the fins in the ingoing configuration will result in lines crossing if they are drawn sufficiently long. To solve the problem, configurations similar to those shown in Figure 2.6 are used. However, using the impoverished configuration does not seem to alter the psychophysical function between magnitude of illusion to fin length

Figure 2.6: An example of a configuration used to solve the problem of crossing lines.



(Restle & Decker 1977).

Addition of fins. Pressey and Wilson (1977) compared the magnitude of illusion produced by configurations with two fins with those induced with four fins. An additional set of fins was added to each end of the shaft. The fins of the complex configuration were of the same dimensions as those in two, traditionally drawn configurations. They found illusions produced by composite displays were unequal in magnitude to either the sum or the average of the simple configurations. For the composite outgoing configuration, the illusion was larger than the average illusion produced by its components and for the composite ingoing configuration the illusion was smaller than the illusion produced by either of its components.

Pressey and Wilson (1977) suggested that that the addition of fins had the effect of increasing the apparent length of the shaft which added to the effects on shaft length produced by fins. Since the ingoing illusion is one of shrinkage, increasing the apparent length of the shaft would decrease illusion. For the outgoing configuration, since it is one of expansion, this would increase illusion.

Viewing Conditions

Typically observers view configurations without specialized instructions concerning the way displays should be regarded. It is expected that the displays will be viewed in the way line drawings are normally viewed; i.e., the gaze will be directed towards all components of configurations. Because of the nature of the task, however, it seems likely that the shaft and comparison line would be the object of the gaze more often than the other parts of the configuration. Under this set of instructions, which is called free inspection, light rays from all components of configurations become directed to both sides of each retina. The retina then sends neural impulses through the ascending tract of the visual system. Because both sides of each retina become stimulated by light rays reflected from the entire configuration and because of the physiology of the visual system, left and right hemispheres of the brain become stimulated with similar information concerning the nature of the configuration.

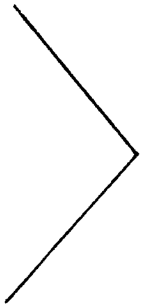
The sequence described above can be altered either through instructions or through presentation of configurations with specialized apparataus. In this part of the chapter studies which alter the typical sequence of events will be examined.

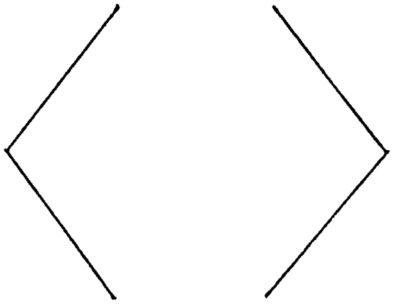
Restriction of scanning (fixation). One way to reduce the amount of scanning is to require observers to fixate either part of a configuration or a point located near the configuration. When asked to fixate, observers are told to direct their gaze at a particular location and to keep it steady at that location while making their judgment. If observers do follow instructions, and if scanning is involved in producing illusion, then fixation would alter illusion.

Day (1962), who required observers to set the outgoing component equal in length to the ingoing part, with a configuration similar to the one shown in Figure 2.7, compared the magnitude of illusion under fixation and free inspection. When asked to fixate, observers, directed their gaze towards the middle fin. Day found that the illusion was approximately twice as large with fixation as with free inspection.

Day also compared the effects of location of fixation. Observers fixated either the middle fin (central fixation) or above the middle fin (eccentric fixation). Magnitude of illusion was approximately 40%

Figure 2.7: A display similar to the one used by Day (1962).





larger under central fixation than under eccentric fixation. However, this difference dissipated with practice. Thus fixation and possibly the location of fixation altered illusion.

Stabilized configurations. One traditional explanation suggests that illusions develop from eye-movements (Carr, 1935). The argument is made that there is a direct relationship between apparent size of shaft and the amount of eye-movement which occurs during scanning of the shaft. On this theory, if fins restrict or increase the magnitude of eye-movements, then eye-movements could be involved directly in producing illusion. If eye-movements do produce illusion, elimination of their occurrence would abolish illusion. The findings of Day (1962), on the effects of fixation, appear sufficent to refute explanations based on eye-movements. However, there are difficulties in accepting arguments based on fixation as providing sufficient grounds to refute this theory. First, do observers fixate when asked? Unless there is a means of recording movements one cannot be certain. Furthermore even if observers do fixate, how steady is fixation? There is evidence to suggest that fixation is never perfectly steady when observers attempt to fixate since eye-movements are continuously produced under fixation (Riggs, Armington, & Ratliff, 1954). Thus data collected under instructions to fixate do not provide conclusive evidence against eye-movement theory.

One way to circumvent this problem of eye-movements is to stabilize the retinal image. With stabilization, the image of the display, regardless of eye-movements, remains on the same position on the retina. There are two ways stabilization has been accomplished. Pritchard (1958) used an optical system which compensated for eye-movements so that light rays reflected from components of configurations struck the same position on the retina. A second procedure used a bright flash of light to illuminate configurations (Evans & Marsden, 1966). The light was of sufficient intensity so that after-images of configurations were generated. Thus the first procedure produced stabilization physically and the second accomplished stabilization neurally. Under both procedures illusions were found to persist. Thus eye-movements are not a necessary condition to produce illusion.

Stabilized Contextual Components

The studies performed by Pritchard (1958) and by Evans and Marsden (1966) stabilized entire configurations. However, it is possible to stabilize components of configurations. O'Halloran and Weintraub (1977) stabilized the outer circle in the Delboeuf configuration with the procedure used by Evans and Marsden (1966) and then had observers "superimpose" the stabilized circle over the inner test circle. They found that the size of the test circle, which is overestimated in normal viewing, was underestimated. Thus stabilization of the contextual circle prior to observation of the test circle produced an illusion of contrast.

The results obtained by O'Halloran and Weintraub (1977) were similar to those found with successive presentation of contextual and test circles (Ikeda and Obonai, 1955). Both studies showed that presentation of contextual circles0 prior to test circles produced contrast.

Stereoscopic Viewing

At what level of the perceptual system are illusions produced? Do they result from processes occurring at the retina or at some higher level? One way this question is studied is through stereoscopic presentation of displays. Under stereoscopic presentation test and contextual components are presented separately to each eye. This eliminates interaction between the two components of configurations at the retina, but does permit interaction to occur at higher levels. Although the components are presented to separate eyes, the components appear properly aligned because of the design of the stereoscope. Thus although the shaft may be presented to one eye and the fins to the other, the shaft appears positioned between the fins.

The logic underlying studies using stereoscopic presentation is as follows. If illusions result from interaction of processes occurring at the retina, elimination of interaction at the retina will abolish illusion. Consequently, if illusions are eradicated by stereoscopic presentation, a strong case could be made that illusions occur through retinal processes. On the other hand, if illusions persist with stereoscopic viewing, explanations based on processes occurring at higher levels of the perceptual system are needed.

Early work on stereoscopic viewing by Low and Witasik (cited by Schiller & Winer, 1962) indicated that the magnitude of illusion was substantially reduced. Later research by Ohwaki (cited by Robinson, 1972) and Day (1961) also indicated that illusion was reduced with stereoscopic viewing. Ohwaki, because he found illusion to be reduced and Springbett (1961), because he found with several configurations illusion to be abolished, suggested that illusions depended on retinal processes. On the other hand, Day argued against acceptance of this conclusion. First, he noted that his findings and those of Ohwaki's showed that some illusion still occurred with stereoscopic presentation and that this implied a component more central than the retina to be involved in the production of illusion. Secondly, he noted that under stereoscopic viewing binocular rivalry and depth effects (Boring, 1961) confounded the interpretation of findings. That is, the reduction of illusion may have resulted from stereoscopic viewing per se or from the effects of the confounding factors.

Winer and Schiller (1962) attempted to resolve the issue by presenting configurations very rapidly. They had found in pilot studies that rapid presentation abolished the confounding factors of binocular rivalry and depth effects. Under the conditions of their study they found that illusions persisted and were of approximately the same magnitude as those produced under normal viewing. Thus their results lead to the conclusion that retinal processes were not a major factor in producing illusion.

Conclusions The number of dimensions and of attributes within dimensions which affect illusion leads one to believe that explanations of illusion will be complex. To provide a "complete" theory of illusion, the way these dimensions and their attributes affect illusion must be accounted for.

Evidence reviewed in this chapter indicates that neither eye-movements nor processes which occur within the retina provide conditions necessary in the formation of illusions. Thus explanations based on processes at a higher level(s) of the perceptual system are required.

Chapter 3

Theories of Illusions

For over a hundred years, unified consistent theories of illusions have been sought - generally with little success. The plight of many theoretical attempts was described aptly by Robinson (1972), who wrote, "It is often (though not invariably) the case that theories have a characteristic career. An author discovers that one particular illusion figure or small set of figures can be accounted for by a simple principle or a simple mathematical expression. He finds it difficult to apply this successfully to other figures and so introduces another, generally more vague, principle, auxillary to the first. The nature of this second principle makes experimental test of the theory very difficult and contributions to the literature cease." (pg. 18).

In this review we will try to avoid theories fitting the description outlined by Robinson. Furthermore, to make the review of manageable length, many theories which receive little empirical support in the literature and are reviewed in the past (Boring, 1942; Coren & Girgus, 1978; Gregory, 1966; Robinson, 1972; Titchener, 1918; and Woodworth & Schlosberg, 1938) will also go unreviewed here.

The course that will be followed is to consider contemporary theories which combine psychophysical and theoretical analyses. In this way, we will learn about stimulus variables and perceptual processes considered important in understanding illusions. Another reason for this tactic is that theories developed in this way are invariably more precise than theories based solely on hypothetical processes, in specifying functional relationships between magnitude of illusion and alteration of stimulus variables. Restle and Decker (1977) suggested precisness was a desirable characteristic at the present stage of theory. In fact, in regards to the Muller-Lyer illusion they indicated that theories should be sufficiently precise to plot quantitative relationships if they are to be considered theory.

To organize our review, theories will be divided into two categories. One will be based on the principle of contrast and the other will be organized on the principle of averaging. The principle of averaging explains the occurrence of assimilation, which along with contrast has been throughout the years a preferred explanation of the Muller-Lyer illusion (Restle & Decker, 1977).

Theories Based on Contrast

Earlier it was mentioned that contrast refers to perceptual enhancement of physical differences between test and contextual magnitudes. Two theories, one based on adaptation-level (Restle & Decker, 1977; Restle & Merryman, 1968) and one based on focussing of attention (Piaget, 1969), make contrast an integral part of their explanations. Thus for both explanations, specification of appropriate magnitudes to predict alteration of apparent length is required.

Adaptation-level theory. Restle (Restle, 1978; Restle & Merryman, 1968; Restle & Decker, 1977) explains illusions on the basis of adaptation-level theory (Helson, 1964). It is argued that the judged extent of a test line is a function of the length of the test line and the prevailing adaptation-level. Mathematically the components are joined in the equation; $Ja(l)=L/A$; where $Ja(l)$ represents judged extent of line L and A is adaptation level. Adaptation-level is considered to be a norm used as a reference in the formation of judgments. It is formed from the geometric mean of test line extent, length of contextual stimuli, and residual stimuli. The latter could include size of room, past experience, etc. The quantitative expression for adaptation-level is as follows;

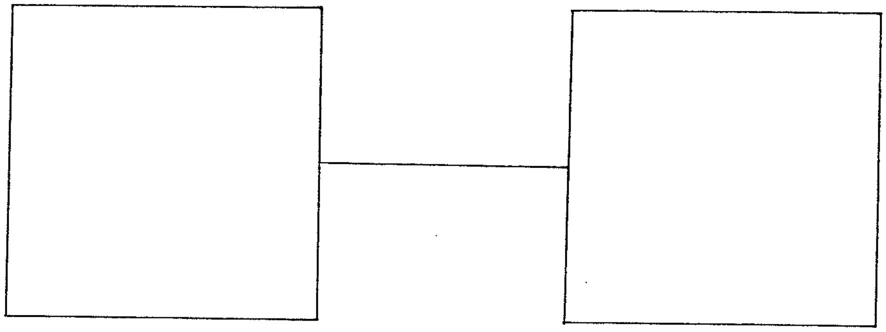
$$A = (L^{s}\ C^{c}\ K^{k})^{[1/(s+c+k)]}$$

where A and L are as defined above, C and K are contextual and residual stimuli, respectively, and s, c, and k, are weighting coefficients for L, C and K respectively.

To understand the theory let us consider first the equation for adaptation-level. When a test line is presented without a specific context, A is formed from a weighted average of L and K. Adding a context results in A formed from all three components. Relative to when only a test line is present, adding a context shorter than L will decrease A. On the other hand, adding a context greater than L increases A. Since Ja(l) is inversely related to A, as is shown in the initial equation above, adding a context shorter than L results in Ja(l) being greater than L, but adding a context longer than L produces a Ja(l) shorter than L.

Adaptation-level theory is clearly applicable to several illusions. Consider for example the illusion produced by the Baldwin configuration shown in Figure 3.1. When boxes are small the shaft appears elongated, and when the boxes are large the shaft appears decreased in length. According to adaptation-level theory, box size is the effective context in altering apparent length. Thus when boxes are shorter than the test length adaptation-level is lowered and the test extent appears elongated. On the other hand, when boxes are larger than the shaft

Figure 3.1: A examples of the Baldwin configuration.



adaptation-level is raised and thus the shaft appears shorten.

Restle and his associates were initially concerned with explaining functional relationships between box size and judged test extent. As predicted by adaptation-level theory, they found that as box size increased apparent shaft length decreased. Studies by Brigell _et al_ (1977) and by Clavadetscher and Anderson (1977) did not confirm the monotonic function between size of box and apparent test extent; instead, they found a nonmonotonic function. The reason for this apparent contradiction among the set of studies lay in the range of box sizes used. Restle and his colleagues used relatively large boxes for their small boxes whereas the others used very small ones. Thus the studies performed with Restle's group involved the downward limb of the function described by the term framing ratio but the other studies used stimuli which encompassed the entire range of the function.

Restle (1978; Restle & Decker, 1977) recently modified adaptation-level theory and it now produces the correct prediction regarding the effects of altering box size. The revised explanation suggests that a field surrounding the test line enters into the formation of adaptation-level and the argument to explain the nonmonotonic relationship is as follows. When a test line is not accompanied by a context and when the context is equal to the size of the display, adaptation-level is of equal magnitude and judgment of the test line is veridical. Presenting a context of smaller magnitude than the size of the field lowers adaptation-level and hence the test line appears increased in length, but presenting a context larger than the field raises adaptation-level and thus decreases the apparent length of the test line. Between the extreme cases of no context and context equal in magnitude to the size of the field, the weight assigned to the context increases with an increase in size of context. As the context approaches these two magnitudes, it has little effect on adaptation-level. But between the two sizes, there is one which maximizes its influence on alteration of adaptation-level and thus has the greatest influence on test length.

For this writer, one of the main attractions of adaptation-level theory is the ease assimilation and contrast are explained in illusions of expansion. As will be found below, some theories become stymied in explaining both type of effects. A major weakness in the theory, as proponents of the theory acknowledge, is that the theory fails to explain many of the important findings associated with illusions of extent - for example, the difference in apparent length between the ingoing and outgoing Muller-Lyer illusions. Thus adaptation-level theory, although it may explain some findings, does not offer a comprehensive explanation of illusions.

Piagetian theory. Piaget (1969) divides illusions into two classes; namely, primary and secondary illusions. Since the Muller-Lyer and other illusions considered here fall within the primary class we are concerned only with this class.

Piaget provides two independent levels of theory; one refers to the processes producing illusions and the second is a quantitative model used to predict relative magnitude of illusion. At one level illusions are held to occur from allocation of attention, or to use Piaget's terminology from centration. The argument is made that when a stimulus receives increased attention it appears increased in size. Although variables such as brightness contrast, duration, etc., are postulated to alter deployment of attention, it is inequality in magnitude which is thought to be most important and hence receives the greatest consideration. It is argued that larger and smaller magnitudes of pair of magnitudes receive greater and lesser attention respectively, then when presented separately. Thus since perceived size varies directly with amount of attention the larger of two magnitudes appears increased in size and the smaller appears decreased.

That attention may play a role in illusion formation is widely acknowledged (Gardner & Long, 1961; Pressey, 1971; Restle, 1971; Robinson, 1972) even by those who prefer explanations based on physiological processes (Walker, 1973). The difficulty with using attention as an explanatory concept, is to provide a means to generate unambiguous predictions - and it is on this basis that Robinson (1972) criticises Piaget's theory. He notes that several studies performed by Piaget and his group could not be considered as providing verification or disconfirmation of this theory.

Whereas there may be ambiguity at the process level of the theory, Piaget's quantitative theorizing is straightforward. At this level Piaget follows an inductive approach. He varies components of displays, measures degree of illusion, and then derives a quantitative expression to predict relative magnitude of illusion. Since his model is based upon contrast, components within displays of unequal length play a major role in his quantitative expression. However, because his approach is also inductive, other features of displays are also incorporated within his formula to predict magnitude of illusion.

Instead of examining Piaget's general mathematical model, which is reviewed elsewhere (Robinson, 1972), we will focus on his explanation of the outgoing Muller-Lyer illusion. The Muller-Lyer is considered to be composed of two trapezoids. As can be seen in Figure 3.2, if the ends between the tips of the fins are joined one trapezoid occurs above the shaft and the second falls below. Within each trapezoid three lengths are deemed important, the shaft a, the base b, and the difference in length between a and b, a′. To explain the illusion Piaget argues that the observer first equates perceptually b with a+2a′; i.e., perceptually b=a+2a′. Then b is compared with a′. Since a′ is shorter than b, and since differences in extent are held to be enhanced, a′ becomes perceptually shorter and b becomes perceptually longer. Since a+2a′=b and since each a′ is devalued in length, for a+2a′ to be equal in length to b, a must be increased in apparent length.

To predict magnitude of illusion the following formula is used;

$$P_1 = \frac{(b-2a')2a'}{bh} \times \frac{a}{b}$$

where b,a and a′ are as defined above, Pl is predicted illusion, and h is the perpendicular distance between the tips of the fins. To test the predictive power of the equation, Piaget altered b but kept a and h constant in the three displays depicted in Figure 3.3. He found that predicted and obtained illusion corresponded closely. Thus it would seem that his quantitative model has some predictive power.

Although the model has some predictive power, this does not imply that Piaget has discovered a quantitative expression which invariably generates correct predictions. Consider for example the prediction made when angle between fins is 90^o and length of fins is increased. When the angle is 90^o, a′ is equal to 1/2 h. Since a=b−2a′, $Pl=[(a)(2a')/(b)(h)]a/b$ Since 2a′=h, $Pl=a^2/b^2$. Now since a is a constant and since b increases with an increase in fin length the model predicts illusion to decrease with an increase in fin length and this clearly does not

Figure 3.2: When the tips are joined by horizontal lines, the Muller-Lyer configuration changes to two trapezoids.

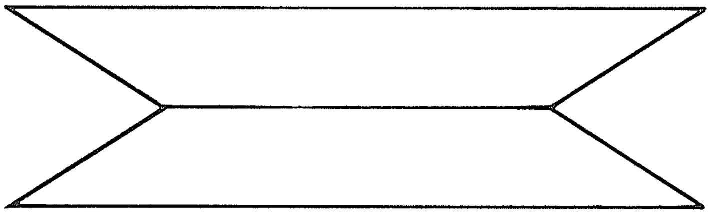
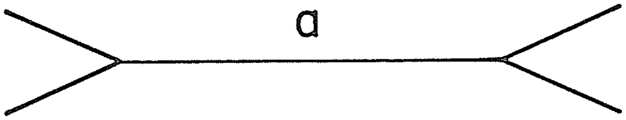
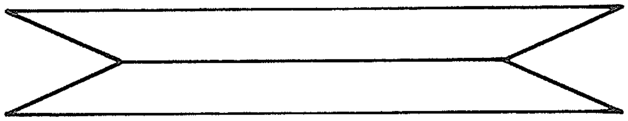


Figure 3.3: The traditional (a), the modified (b), and the Piagetian (c) forms of the Muller-Lyer illusion.

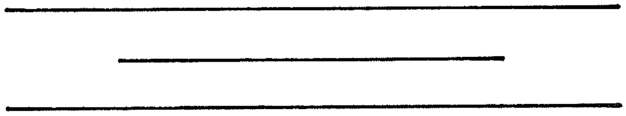
a



b



c



conform to the facts.

Theories Based on Averaging

Assimilation refers to the phenomena of apparent reduction of physical differences and can be explained on the basis of some hypothetical averaging process. For example, illusions induced by Muller-Lyer displays are explained by assuming apparent shaft extent is equal to an average of test and contextual extents (Pressey, 1967). Although a theory based solely on the process of averaging is too simple to explain all data associated with illusions - *e.g.*, the framing ratio function, recent reviews of theories (Robinson, 1972; Coren & Girgus, 1978) acknowledge that some form of averaging is likely to play an important role in the occurrence of illusions. In this portion of the review three theories based on averaging mechanisms will be considered. Two are based on neurological processes and one is cognitively orientated.

Lateral inhibition theory. The term lateral inhibition refers to modification of neural output from one or more receptor units by the activity of other neural units. Since its discovery and subsequent research on variables affecting its occurrence (See Uttal, 1972, for a review) lateral inhibition has become an important explanatory construct in explaining visual phenomena. In the study of illusions lateral inhibition is used to explain the effects of brightness contrast (Wickelgren, 1965) and recently Brigner (1977) has incorporated it within an extensive theory of illusions. In his theory, lateral inhibition is argued to occur among channels sensitive to length and plays the role of generating a weighting function which modifies the magnitude of and the occurrence of assimilation and contrast. As can be seen in Figure 3.4, spatial separation between test and contextual extents is the psychophysical variable underlying the weighting function. When they are near, assimilation occurs but when they are far apart, contrast results. Although Brigner suggests that the shape of the weighting function to be similar across configurations of various size, he indicates also that the specific shape varies with size. To be more specific he predicts that assimilation is more likely to occur with small test extents than with large ones.

Brigner argues, that as well as lateral inhibition, the processes of averaging and summation are also necessary to explain illusions. Since their neurological correlates are unknown he deems it necessary to phrase his theory in psychophysical terminolgy. Thus, his theory states that perceived test extent is equal to an average of weighted test and contextual extents.

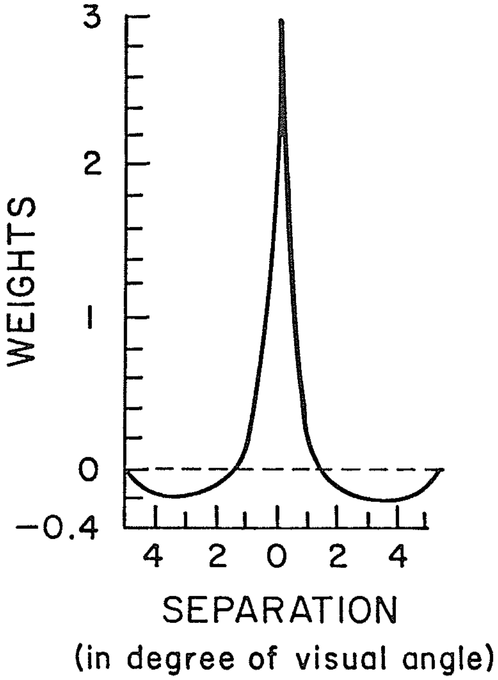
To generate predictions from the theory the following formula may be used;

$$PE = \frac{\sum_{i=1}^{N} (W_i)\ (E_i)}{\sum_{i=1}^{N} W_i}$$

where PE is perceived extent of the test line, Ei is length of extent i, and Wi is the weight assigned to extent i. The formula has been used only to generate qualitative predictions and in this regard it does have some predictive power. A true test of its power, however, would be to compare predicted and obtained functional relationships between alteration of stimulus variables and degree of illusion.

The novel aspect of this theory is the weighting function. Since lateral inhibition is an established fact, the weighting function is not based on some speculative process. From a psychophysical point of view the weighting function is also intriguing because it specifies precisely

Figure 3.4: The weighting function proposed by Brigner (1977). Positive values produce assimilation and negative values produce contrast.

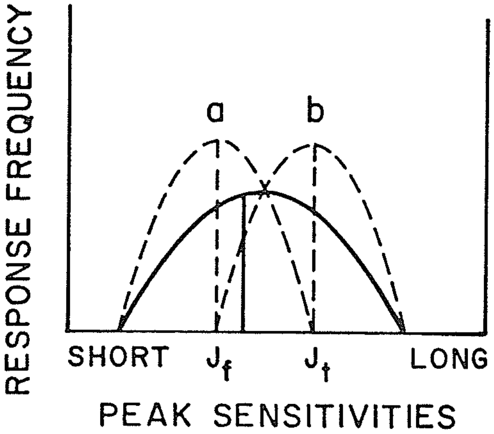

3
2
1
0
−0.4
WEIGHTS
4
2
0
2
4
SEPARATION
(in degree of visual angle)

the variable involved in producing assimilation and contrast. If this was shown to be true, a major step forward would be made in understanding illusions.

The theory does have some difficulties. First, it predicts magnitude of ingoing and outgoing Muller-Lyer illusion to be of equal magnitude, which is not true (Bayer & Pressey, 1972). Second, a linear increase in illusion is predicted when contextual extents are increased in length with the Piagetian form of the Muller-Lyer illusion (See Figure 3.3c), but findings indicate the function to be nonmonotonic (Piaget, 1969). Thus the theory, although its merits consideration, does have several weaknesses.

<u>Framing theory.</u> Brigell, Uhlarik, and Goldhorn (1977) use the idea of framing to explain illusions. They argue that total configurational extent acts as a frame surrounding the test extent and that the frame alters the apparent length of the test line. To account for the effects of frame, an explanation based upon the notion of channels which respond selectively to length, is offered. The channels are assumed to have the following characteristics. First, individual channels respond optimally to one extent and are sensitive only to a limited range of extents. Furthermore, as extents diverge from the one triggering maximum responding, the level of responding decreases. Second, the pattern of responding among all channels is identical. Thus the pattern produced by the population of length sensitive channels to a given extent is identical to reponse characteristics of channels responding optimally to that extent. Third, when more than one extent is viewed the pattern of responses produced is an algebraic average of responses produced when the extents are displayed individually (See Figure 3.5). It is this

Figure 3.5: The dashed curves depict the pattern of firing produced by test and configurational extents. The solid curve shows the algebraic average of the two patterns.


RESPONSE FREQUENCY
a
b
SHORT
J_f
J_t
LONG
PEAK SENSITIVITIES

latter feature which is responsible for illusions. Illusions occur when responses to the test extent differ between presentation of the shaft by itself and when the shaft is embedded in a context of greater extent.

At the present time framing theory should be considered as offering only a limited theory of illusions. As proponents of the theory realize, variables other than configurational size alter apparent extent. Nevertheless, the theory is powerful in the sense that it explains easily the framing ratio function. It could be made even more powerful if contextual extent rather than configurational size is made to be the context affecting perceived extent, since this would allow shrinkage illusions to be explained by the theory.

Assimilation theory. Pressey (1967) theorizes that the Muller-Lyer and other illusions of extent are explicable on the assumption that perceived test is an average of all distances parallel to the shaft which are formed between the pair of opposing wings. Since its initial formulation, the theory has become more elaborate and presently it states that degree of illusion is a weighted average of test and contextual extents. Factors entering into the weighting process are attention, separation, and the difference in length between test and contextual extents - the range factor.

Pressey (1972) discovered the importance of range when he tried to ascertain the underlying basis between alteration of wings and degree of illusion. He found that range covaried linearly with the effects of alteration of size of angle. Range was then incorporated within assimilation theory in a postulate which maintained that degree of assimilation illusion increased with increased range.

The role of attention is explained by the concept of attentive fields. Attentive fields are maintained to be roughly circular areas from where observers process information. They are given the property of modulating the effect of contextual extents on apparent test length - the closer a contextual length is to the center of the field the more effective it is. The center of the field is operationally defined as the midpoint between the most separated elements required to perform the task.

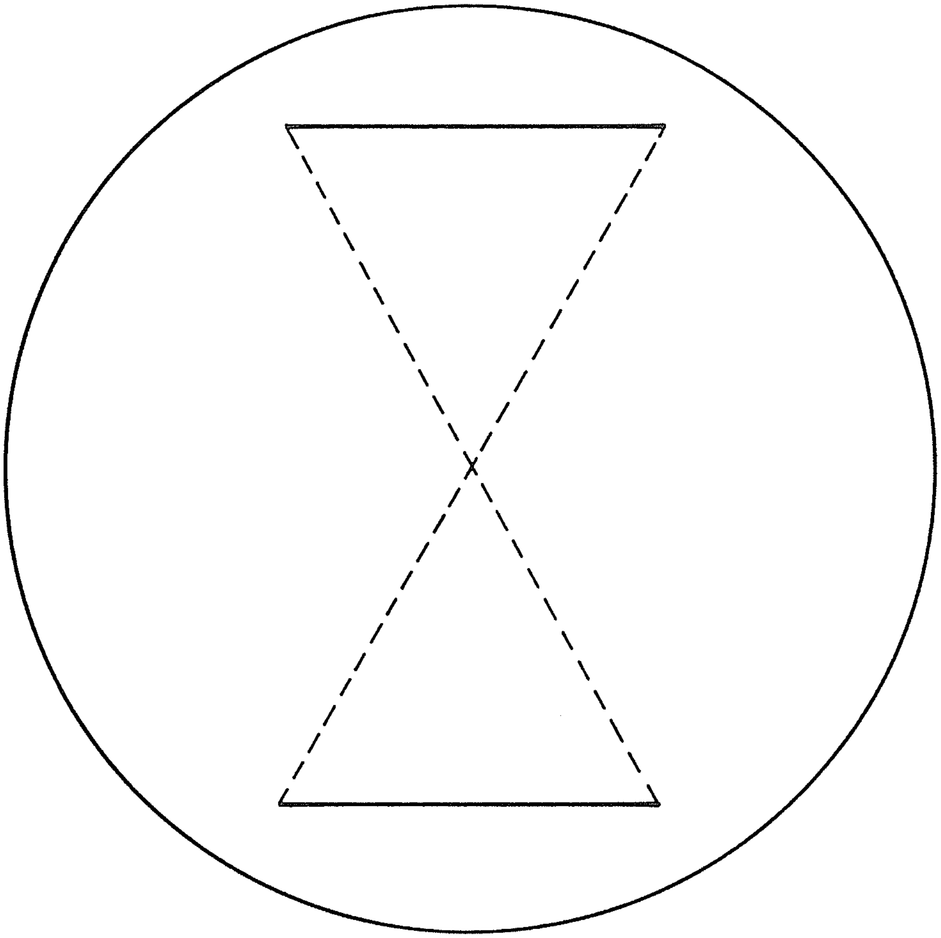
The following example demonstrates how one may locate the center of an attentive field. Let it be assumed that an observer is required to compare the lengths of lines a and b in figure 3.6. Since the endpoints of each line are the most widely separated components needed to perform the task, the center of the field lies midway between the ends. The center of the field is found by connecting these points and finding where they intersect. It is at the point of intersection where the center of the field lies.

An attentive fields is an useful explanatory tool. It allows illusions, induced by complex configurations such as the Ponzo, to be explained in a straightforward way and it has generated predictions unique to assimilation theory which have been subsequently verified (Pressey, 1974; Pressey & Bross, 1973; Wilson & Harper, 1977).

Failure to verify one prediction generated from attentive fields led Pressey and Murray (1976) to appreciate the role separation plays in illusions. They found, with the parallel line illusion, that when response and contextual lines lay on the same side of the test line, illusion decreased in magnitude when the contextual line approached the center of the field.

These findings are explained by the construct of an interactive

Figure 3.6: The circle represents an attentive field. The point, where the dashed lines intersects, represents the center of the field.



field. An interactive fields is a logical construct designed explicitly to explain the effects of separation. It is operationally defined as a circular region with its midpoint located at the endpoint of the test line and is given the property that the closer the tip of a contextual extent lies to the center of the field the more effective it is in altering the appearance of the test line.

Recently, Pressey and Wilson (1980) used interactive fields to explain contrast. They suggest that the field can be divided into two regions; an inner one which produces assimilation and an outer one which generates contrast. Therefore, from this formulation of an interactive field, contrast may occur by either increasing separation or by altering contextual extent.

Assimilation theory offers a powerful explanation of illusions and of data associated with illusions. The factors are combined quantitatively, in a formula used to predict magnitude of illusion, and research which tests the accuracy of the formula generally find close correspondence between obtained and predicted magnitudes of illusions (Pressey & Di Lollo, 1979; Pressey, Di Lollo, & Tait, 1978; Pressey & Murray, 1976). Furthermore, as mentioned above, several predictions unique to assimilation theory have been verified. Nonetheless, the theory is faced with several difficulties. First the theory predicts greater ingoing than outgoing illusion, which is not true and it does not explain the illusion associated with the H configuration (Restle & Decker, 1977).

Conclusions It is clear from this brief review that each theory is developed from a common approach. Proponents of the theories alter configurational properties and study the effect on degree of illusion.

Then constructs are proposed to account for the functional relationships discovered.

Although the theories differ widely in terms of explanatory constructs, they share a common ground in regards to the variables held to be most important in understanding illusions. They each acknowledge the role contextual extent plays in altering illusion and some agree that separation is also an important variable.

Appendix B

Average Raw Deviation Scores in Units of .075 mm

Experiment I

Sequence 1
Subject 1

Spatial Separation	Contextual Length								
	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	5.0	1.0	-2.0	9.0	2.0	-7.0	3.0	7.0	8.0
Above									
2.1	3.	-3.	5.	3.	0.	-7.	7.	-1.	-2.
4.2	4.	-8.	1.	4.	5.	2.	-1.	8.	2.
8.4	0.	-6.	4.	0.	-4.	3.	-5.	2.	5.
14.7	3.	2.	-3.	-2.	-4.	-8.	-2.	1.	5.
Below									
2.1	-3.	-5.	13.	3.	-1.	-7.	1.	-5.	-3.
4.2	1.	1.	-1.	-3.	-7.	-3.	-5.	-2.	-4.
8.4	4.	-8.	-1.	-1.	1.	8.	0.	-1.	2.
14.7	-2.	-6.	6.	-7.	-3.	-4.	5.	7.	-1.

Sequence 1
Subject 2

Spatial Separation	Contextual Length								
	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	10.0	11.0	28.0	16.0	27.0	11.0	3.0	15.0	14.0
Above									
2.1	7.	16.	8.	28.	11.	17.	18.	28.	29.
4.2	3.	16.	8.	31.	23.	28.	11.	13.	32.
8.4	8.	27.	18.	14.	14.	16.	4.	-1.	15.
14.7	-3.	15.	14.	16.	13.	10.	18.	11.	5.
Below									
2.1	14.	14.	28.	35.	22.	21.	20.	16.	25.
4.2	2.	13.	16.	40.	25.	16.	-2.	13.	9.
8.4	-6.	17.	12.	25.	28.	14.	7.	22.	16.
14.7	9.	8.	15.	20.	32.	22.	21.	19.	43.

Sequence 1
Subject 3

	Contextual Length								
Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	-3.0	-10.0	15.0	16.0	4.0	25.0	3.0	11.0	12.0
Above									
2.1	-18.	23.	4.	18.	3.	8.	18.	22.	-6.
4.2	-32.	3.	10.	28.	18.	9.	5.	16.	3.
8.4	-20.	-6.	1.	23.	18.	14.	15.	18.	6.
14.7	-9.	16.	10.	20.	30.	15.	6.	17.	3.
Below									
2.1	-19.	8.	9.	17.	30.	15.	-4.	7.	6.
4.2	-8.	-6.	9.	17.	3.	17.	16.	10.	18.
8.4	-14.	-1.	-3.	32.	10.	14.	15.	-21.	6.
14.7	-6.	-3.	1.	10.	12.	19.	8.	17.	23.

Sequence 2
Subject 4

	Contextual Length								
Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	3.0	-2.0	9.0	13.0	15.0	16.0	-3.0	9.0	16.0
Above									
2.1	6.	7.	12.	9.	8.	18.	18.	11.	22.
4.2	15.	9.	15.	20.	18.	27.	15.	18.	14.
8.4	10.	1.	5.	12.	16.	17.	24.	15.	16.
14.7	4.	-1.	4.	10.	10.	19.	9.	19.	17.
Below									
2.1	-3.	1.	33.	19.	18.	27.	5.	16.	7.
4.2	-4.	0.	8.	21.	18.	22.	8.	8.	16.
8.4	13.	-2.	2.	15.	15.	21.	17.	15.	11.
14.7	7.	7.	8.	19.	19.	13.	16.	7.	11.

Sequence 2
Subject 5

Spatial Separation	Contextual Length 22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	21.0	10.0	17.0	20.0	17.0	8.0	8.0	6.0	-9.0
Above									
2.1	-4.	-3.	11.	17.	25.	14.	25.	39.	2.
4.2	-3.	-10.	3.	28.	35.	23.	21.	4.	16.
8.4	-9.	39.	8.	14.	-2.	10.	15.	9.	0.
14.7	1.	-3.	2.	11.	13.	1.	19.	-3.	14.
Below									
2.1	5.	-5.	13.	40.	32.	23.	23.	10.	18.
4.2	3.	13.	16.	44.	35.	15.	30.	6.	5.
8.4	2.	-21.	27.	28.	38.	29.	19.	28.	-3.
14.7	16.	7.	9.	30.	21.	29.	13.	28.	12.

Sequence 2
Subject 6

Contextual Length

Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	-11.0	-8.0	-10.0	-13.0	-16.0	-12.0	-22.0	-33.0	-21.0
Above									
2.1	-36.	-1.	-1.	0.	6.	-19.	-9.	-24.	-21.
4.2	-36.	-13.	-3.	-5.	-6.	-14.	-5.	-21.	-15.
8.4	-11.	-13.	-5.	2.	-5.	-7.	-9.	-14.	-21.
14.7	-9.	-21.	-2.	-16.	-14.	-16.	-19.	-24.	-14.
Below									
2.1	-26.	-20.	-6.	-3.	0.	-6.	-7.	-19.	-19.
4.2	-21.	-10.	0.	1.	-6.	-10.	-13.	-17.	-27.
8.4	-14.	-7.	-2.	-11.	-6.	-13.	-8.	-21.	-21.
14.7	-16.	11.	-4.	-9.	-17.	-5.	4.	-14.	-20.

Sequence 3
Subject 7

Spatial Separation	Contextual Length 22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	14.0	20.0	-2.0	-1.0	-8.0	3.0	1.0	11.0	6.0
Above									
2.1	-12.	0.	-7.	2.	12.	9.	5.	15.	9.
4.2	-13.	3.	7.	12.	27.	4.	0.	-1.	5.
8.4	0.	4.	-12.	-12.	20.	6.	9.	4.	11.
14.7	3.	9.	-14.	17.	3.	14.	12.	6.	15.
Below									
2.1	4.	17.	11.	33.	14.	18.	6.	16.	6.
4.2	2.	16.	16.	33.	30.	27.	20.	11.	1.
8.4	5.	9.	9.	33.	16.	-1.	6.	13.	8.
14.7	6.	15.	12.	26.	26.	28.	16.	8.	2.

Sequence 3
Subject 8

Spatial Separation	Contextual Length								
	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	-8.0	5.0	-5.0	-8.0	6.0	-8.0	-4.0	0.0	-6.0
Above									
2.1	-5.	-4.	2.	25.	19.	20.	10.	10.	1.
4.2	-4.	-11.	-3.	20.	33.	9.	9.	7.	2.
8.4	-10.	-2.	11.	25.	2.	12.	4.	-2.	-2.
14.7	-2.	0.	0.	3.	7.	-8.	-6.	11.	10.
Below									
2.1	-5.	-9.	17.	38.	33.	42.	11.	21.	6.
4.2	5.	-8.	3.	37.	51.	21.	36.	3.	12.
8.4	9.	6.	8.	42.	30.	21.	30.	-1.	5.
14.7	-19.	1.	6.	13.	15.	3.	-2.	11.	3.

Sequence 3
Subject 9

	Contextual Length								
Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	-1.0	3.0	11.0	21.0	11.0	4.0	8.0	7.0	-7.0
Above									
2.1	-7.	-12.	17.	20.	9.	24.	21.	16.	17.
4.2	-10.	-2.	11.	-7.	25.	1.	6.	13.	5.
8.4	5.	9.	24.	14.	-4.	3.	19.	13.	7.
14.7	0.	14.	10.	14.	0.	19.	4.	-2.	11.
Below									
2.1	-21.	4.	37.	27.	12.	17.	13.	-2.	7.
4.2	-17.	-2.	0.	11.	14.	13.	30.	4.	5.
8.4	-7.	-1.	9.	9.	11.	10.	8.	5.	5.
14.7	15.	6.	14.	4.	11.	9.	22.	14.	8.

Sequence 4
Subject 10

Contextual Length

Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	4.0	10.0	7.0	11.0	7.0	-3.0	10.0	12.0	9.0
Above									
2.1	-1.	3.	17.	29.	21.	19.	1.	-8.	12.
4.2	3.	11.	9.	21.	9.	8.	4.	1.	4.
8.4	3.	0.	18.	15.	15.	7.	0.	-1.	16.
14.7	17.	6.	6.	-1.	1.	5.	8.	5.	13.
Below									
2.1	1.	16.	18.	32.	26.	32.	-1.	0.	7.
4.2	-7.	7.	18.	32.	18.	25.	16.	12.	7.
8.4	10.	6.	7.	23.	23.	22.	18.	7.	3.
14.7	10.	-4.	7.	12.	6.	11.	6.	6.	9.

Sequence 4
Subject 11

Spatial Separation	Contextual Length								
	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	-9.0	0.0	2.0	-3.0	-1.0	4.0	-13.0	-11.0	-1.0
Above									
2.1	-8.	-12.	7.	6.	-3.	-6.	3.	-4.	0.
4.2	-5.	0.	-1.	0.	6.	3.	-3.	-1.	-4.
8.4	-15.	-5.	1.	1.	-13.	5.	13.	-8.	4.
14.7	-4.	15.	1.	-2.	1.	1.	5.	6.	3.
Below									
2.1	0.	-1.	8.	8.	9.	0.	-14.	5.	-2.
4.2	-10.	0.	0.	21.	6.	9.	-7.	-1.	-10.
8.4	-9.	-13.	2.	11.	-2.	-5.	-3.	0.	-3.
14.7	-4.	5.	8.	-6.	2.	-9.	0.	-10.	0.

Sequence 4
Subject 12

	Contextual Length								
Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	18.0	27.0	19.0	2.0	21.0	17.0	17.0	20.0	12.0
Above									
2.1	9.	8.	14.	17.	31.	12.	13.	21.	20.
4.2	6.	8.	11.	22.	16.	14.	13.	12.	25.
8.4	9.	5.	3.	10.	11.	5.	19.	13.	20.
14.7	8.	6.	15.	0.	4.	-2.	23.	19.	18.
Below									
2.1	9.	20.	24.	48.	34.	19.	14.	22.	16.
4.2	-2.	16.	12.	29.	38.	25.	23.	20.	11.
8.4	7.	11.	17.	23.	31.	16.	13.	23.	4.
14.7	4.	7.	6.	19.	22.	21.	20.	12.	14.

Sequence 5
Subject 13

	Contextual Length								
Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	5.0	4.0	4.0	-3.0	-13.0	8.0	2.0	-5.0	-7.0
Above									
2.1	-20.	-9.	3.	-9.	-9.	-9.	-15.	-14.	-14.
4.2	-8.	-23.	-7.	-4.	-6.	1.	-8.	-3.	-13.
8.4	-11.	-7.	4.	-5.	2.	-3.	-1.	-10.	-7.
14.7	2.	1.	8.	0.	-10.	2.	-2.	-10.	-4.
Below									
2.1	-3.	-7.	8.	11.	-1.	-10.	0.	-7.	-27.
4.2	-15.	-1.	16.	8.	5.	2.	-13.	-4.	-11.
8.4	5.	-10.	32.	19.	-4.	14.	6.	0.	-9.
14.7	1.	9.	0.	10.	9.	-5.	13.	-9.	-4.

Sequence 5
Subject 14

Contextual Length

Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	4.0	8.0	-3.0	2.0	-1.0	0.0	-11.0	3.0	-5.0
Above									
2.1	-21.	-20.	-1.	-5.	7.	2.	-4.	4.	-8.
4.2	-12.	-9.	-4.	-3.	0.	-5.	-1.	0.	-6.
8.4	-15.	-1.	1.	0.	-2.	1.	-6.	-8.	-8.
14.7	-5.	-5.	-5.	-4.	7.	-1.	-1.	-11.	-1.
Below									
2.1	-20.	-10.	-11.	3.	3.	-6.	-4.	-15.	-5.
4.2	-21.	-6.	-3.	-5.	7.	5.	2.	-9.	-7.
8.4	-17.	-5.	-6.	7.	3.	-2.	-2.	-8.	-9.
14.7	-14.	8.	-8.	18.	-3.	-7.	-3.	-2.	2.

Sequence 5
Subject 15

	Contextual Length								
Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	13.0	22.0	20.0	15.0	4.0	2.0	5.0	15.0	6.0
Above									
2.1	8.	3.	11.	19.	5.	5.	6.	-3.	-2.
4.2	11.	10.	11.	32.	8.	-12.	15.	10.	2.
8.4	15.	27.	0.	9.	6.	-6.	-3.	10.	4.
14.7	17.	10.	26.	23.	4.	-9.	11.	15.	4.
Below									
2.1	6.	16.	20.	17.	7.	-16.	1.	-6.	-3.
4.2	33.	7.	27.	21.	-10.	-10.	-1.	2.	-7.
8.4	2.	7.	4.	19.	-7.	7.	5.	11.	6.
14.7	11.	5.	16.	13.	-6.	3.	1.	4.	-8.

Sequence 6
Subject 16

Contextual Length

Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	3.0	-1.0	-11.0	-13.0	-7.0	4.0	14.0	12.0	-1.0
Above									
2.1	-2.	2.	3.	7.	11.	0.	16.	-4.	-1.
4.2	5.	-16.	-9.	4.	3.	-9.	1.	8.	5.
8.4	-8.	-7.	5.	0.	1.	-6.	-14.	-4.	2.
14.7	2.	0.	9.	-5.	0.	-5.	-4.	-1.	-1.
Below									
2.1	-2.	9.	14.	24.	15.	2.	2.	0.	6.
4.2	-3.	0.	14.	10.	11.	2.	6.	7.	-13.
8.4	-4.	7.	12.	15.	0.	14.	9.	1.	0.
14.7	-6.	3.	-8.	-6.	1.	-1.	-5.	-1.	15.

Sequence 6
Subject 17

	Contextual Length								
Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	12.0	24.0	15.0	15.0	22.0	13.0	16.0	19.0	25.0
Above									
2.1	19.	29.	19.	25.	18.	34.	17.	17.	19.
4.2	20.	21.	24.	18.	25.	31.	15.	12.	15.
8.4	21.	21.	27.	21.	13.	16.	21.	29.	21.
14.7	14.	22.	17.	20.	11.	17.	15.	11.	19.
Below									
2.1	15.	18.	21.	28.	19.	19.	13.	16.	14.
4.2	10.	24.	20.	17.	11.	16.	19.	13.	10.
8.4	14.	25.	25.	27.	7.	17.	17.	19.	16.
14.7	13.	14.	12.	14.	17.	16.	15.	11.	15.

Sequence 6
Subject 18

Contextual Length

Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	-6.0	4.0	-2.0	10.0	2.0	15.0	5.0	3.0	24.0
Above									
2.1	-25.	0.	13.	10.	17.	9.	0.	20.	1.
4.2	-20.	-19.	5.	18.	7.	2.	3.	6.	7.
8.4	1.	-10.	4.	0.	11.	6.	1.	9.	10.
14.7	5.	-1.	8.	17.	7.	-7.	-3.	9.	-10.
Below									
2.1	-17.	-9.	16.	18.	24.	11.	12.	4.	4.
4.2	-21.	13.	18.	14.	21.	1.	-3.	1.	4.
8.4	-4.	3.	5.	14.	12.	-1.	3.	7.	-7.
14.7	-22.	4.	3.	21.	10.	-3.	-16.	12.	-7.

Sequence 7
Subject 19

Contextual Length

Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	4.0	1.0	2.0	-4.0	-10.0	6.0	-2.0	3.0	14.0
Above									
2.1	2.	6.	-14.	-12.	0.	-7.	0.	6.	4.
4.2	-1.	8.	2.	-11.	7.	9.	2.	4.	12.
8.4	-3.	-12.	-5.	-6.	-7.	-2.	-1.	0.	7.
14.7	4.	6.	-6.	13.	1.	-6.	-8.	6.	7.
Below									
2.1	-10.	8.	1.	-5.	2.	2.	2.	6.	-14.
4.2	-3.	-6.	-2.	-4.	7.	-8.	-15.	-1.	1.
8.4	-5.	-4.	7.	0.	-1.	-11.	-7.	7.	0.
14.7	-5.	3.	-8.	-3.	5.	-2.	1.	-6.	-5.

Sequence 7
Subject 20

Contextual Length

Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	7.0	7.0	11.0	18.0	25.0	4.0	4.0	1.0	5.0
Above									
2.1	2.	12.	8.	20.	21.	23.	2.	14.	-3.
4.2	-2.	-2.	7.	15.	4.	23.	9.	12.	21.
8.4	-2.	3.	-2.	10.	6.	15.	2.	-4.	13.
14.7	4.	5.	5.	15.	4.	8.	-1.	0.	14.
Below									
2.1	7.	10.	25.	51.	47.	23.	11.	-3.	-3.
4.2	13.	11.	21.	25.	15.	11.	16.	3.	10.
8.4	-9.	11.	20.	26.	24.	1.	3.	0.	11.
14.7	27.	13.	19.	11.	11.	10.	8.	4.	-1.

Sequence 7
Subject 21

	Contextual Length								
	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
Spatial Separation									
control	2.0	-1.0	-1.0	3.0	5.0	4.0	-4.0	-8.0	-1.0
Above									
2.1	-7.	9.	14.	20.	11.	11.	15.	7.	4.
4.2	-5.	6.	12.	17.	2.	13.	15.	1.	12.
8.4	-2.	-1.	19.	7.	-1.	11.	-2.	-2.	-5.
14.7	-6.	2.	5.	-3.	11.	9.	6.	7.	-6.
Below									
2.1	-16.	6.	15.	10.	11.	6.	9.	7.	11.
4.2	-17.	2.	11.	11.	6.	14.	9.	-4.	-4.
8.4	-16.	-12.	5.	6.	9.	13.	9.	-11.	1.
14.7	-4.	10.	11.	6.	14.	-1.	5.	16.	0.

Sequence 8
Subject 22

Contextual Length

Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	2.0	1.0	0.0	-15.0	-18.0	-12.0	5.0	-9.0	0.0
Above									
2.1	5.	-1.	-13.	-19.	-4.	-5.	-5.	20.	4.
4.2	-6.	3.	-15.	-15.	10.	-16.	2.	2.	9.
8.4	-8.	-19.	-7.	-12.	-2.	1.	-6.	-5.	5.
14.7	-7.	-1.	-29.	-17.	-5.	-11.	-3.	3.	0.
Below									
2.1	-2.	-1.	-8.	12.	7.	-6.	22.	-14.	15.
4.2	-14.	-7.	6.	2.	-2.	-10.	-7.	-2.	-8.
8.4	-1.	9.	-21.	-10.	-23.	1.	-4.	-1.	4.
14.7	16.	-14.	-1.	-19.	5.	19.	15.	2.	17.

Sequence 8
Subject 23

Contextual Length

Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	7.0	8.0	0.0	-7.0	-2.0	-6.0	1.0	1.0	-1.0
Above									
2.1	-11.	-6.	6.	8.	2.	-3.	11.	1.	8.
4.2	-2.	5.	1.	7.	2.	1.	-2.	3.	7.
8.4	-6.	0.	3.	-1.	-2.	10.	-4.	1.	1.
14.7	-5.	-1.	0.	-5.	5.	3.	1.	-1.	4.
Below									
2.1	-7.	1.	16.	9.	7.	12.	6.	6.	7.
4.2	-7.	8.	15.	-1.	12.	4.	3.	7.	-4.
8.4	-5.	1.	-2.	2.	13.	-8.	9.	-2.	0.
14.7	-12.	6.	6.	-7.	0.	-1.	8.	6.	13.

Sequence 8
Subject 24

	Contextual Length								
Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	7.0	13.0	12.0	4.0	5.0	0.0	-3.0	-3.0	-5.0
Above									
2.1	-4.	9.	8.	4.	9.	14.	15.	-6.	-7.
4.2	-1.	2.	20.	9.	8.	12.	12.	-5.	0.
8.4	-7.	5.	16.	0.	14.	13.	16.	4.	-9.
14.7	-4.	20.	9.	9.	-1.	11.	8.	-12.	5.
Below									
2.1	11.	6.	18.	10.	9.	14.	16.	-10.	5.
4.2	-1.	10.	-3.	19.	13.	19.	3.	-3.	-6.
8.4	1.	2.	11.	9.	16.	6.	8.	1.	-1.
14.7	6.	16.	16.	7.	10.	13.	3.	11.	5.

Sequence 9
Subject 25

Contextual Length

Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	15.0	10.0	7.0	3.0	9.0	7.0	-3.0	6.0	8.0
Above									
2.1	-2.	4.	0.	22.	1.	9.	-1.	5.	13.
4.2	3.	1.	2.	6.	16.	12.	10.	4.	19.
8.4	11.	8.	-2.	8.	12.	3.	9.	-2.	12.
14.7	8.	5.	3.	18.	5.	12.	3.	-4.	9.
Below									
2.1	5.	10.	15.	12.	6.	7.	8.	0.	9.
4.2	3.	9.	19.	18.	20.	11.	2.	-12.	12.
8.4	6.	16.	17.	13.	23.	10.	5.	-6.	-2.
14.7	6.	15.	12.	-4.	17.	13.	8.	0.	1.

Sequence 9
Subject 26

Spatial Separation	Contextual Length								
control	16.0	10.0	-2.0	3.0	6.0	8.0	0.0	3.0	5.0
Above									
2.1	16.	12.	10.	18.	20.	-2.	5.	-3.	5.
4.2	2.	4.	18.	13.	12.	13.	5.	2.	8.
8.4	5.	7.	5.	7.	1.	8.	2.	11.	4.
14.7	-10.	9.	-2.	2.	-1.	10.	-7.	-1.	11.
Below									
2.1	5.	5.	7.	17.	4.	4.	1.	7.	13.
4.2	4.	5.	16.	20.	11.	6.	5.	4.	6.
8.4	7.	6.	6.	10.	15.	8.	-3.	4.	6.
14.7	9.	12.	5.	16.	13.	5.	7.	4.	16.

Sequence 9
Subject 27

	Contextual Length								
Spatial Separation	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
control	17.0	25.0	2.0	4.0	5.0	10.0	2.0	-3.0	21.0
Above									
2.1	-2.	13.	8.	12.	8.	15.	4.	6.	-2.
4.2	10.	13.	3.	11.	5.	2.	10.	4.	5.
8.4	-2.	6.	5.	9.	-6.	6.	9.	6.	-2.
14.7	4.	10.	3.	1.	6.	2.	12.	-1.	2.
Below									
2.1	13.	0.	18.	24.	2.	1.	-1.	-1.	6.
4.2	-3.	12.	11.	8.	9.	6.	12.	0.	-1.
8.4	20.	2.	5.	7.	6.	-3.	1.	14.	2.
14.7	6.	21.	6.	20.	5.	14.	7.	2.	9.

Experiment II

			Above				Below			
		Control	Spatial Separation							
			2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
Trial	Length									
1	22.80	13.	13.	7.	12.	-1.	8.	14.	13.	14.
1	24.25	8.	11.	18.	19.	18.	19.	14.	27.	10.
2	22.80	24.	-1.	-3.	1.	14.	3.	12.	5.	21.
2	24.25	11.	4.	12.	10.	10.	13.	2.	17.	7.
1	22.80	3.	-7.	-5.	10.	-2.	12.	5.	17.	18.
1	24.25	2.	14.	8.	-3.	11.	5.	18.	28.	9.
2	22.80	4.	5.	20.	11.	14.	14.	5.	6.	20.
2	24.25	16.	-11.	3.	1.	8.	16.	1.	4.	21.
1	22.80	-8.	-29.	-28.	0.	-23.	29.	9.	7.	0.
1	24.25	-18.	-19.	0.	-25.	-14.	44.	23.	9.	45.
2	22.80	-22.	-9.	-26.	-19.	-23.	-8.	-14.	-12.	0.
2	24.25	-12.	-3.	-21.	-8.	-9.	-5.	6.	-24.	-8.
1	22.80	6.	-8.	-1.	-13.	-2.	-8.	-18.	-17.	-12.
1	24.25	1.	9.	7.	-1.	1.	-2.	-1.	-4.	-16.
2	22.80	12.	-8.	-5.	6.	-1.	7.	-12.	-9.	-6.
2	24.25	9.	7.	-2.	8.	-1.	-1.	-5.	-14.	-12.
1	22.80	7.	11.	20.	12.	15.	35.	20.	25.	22.
1	24.25	12.	28.	12.	31.	21.	25.	31.	15.	19.
2	22.80	23.	12.	-2.	4.	11.	6.	12.	20.	18.
2	24.25	26.	10.	-2.	20.	34.	10.	36.	32.	23.
1	22.80	-4.	-11.	-8.	8.	7.	-5.	-3.	6.	9.
1	24.25	8.	4.	7.	-4.	-9.	4.	17.	9.	12.
2	22.80	-1.	-10.	-15.	8.	11.	14.	1.	14.	-5.
2	24.25	14.	-10.	2.	1.	8.	17.	18.	-4.	3.

			Above				Below			
		Control	Spatial Separation							
			2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
Trial	Length									
1	22.80	-1.	10.	-7.	-3.	-2.	-6.	6.	1.	-7.
1	24.25	-2.	-10.	-9.	7.	-2.	4.	4.	4.	-2.
2	22.80	-5.	0.	-11.	-12.	3.	11.	1.	-3.	-1.
2	24.25	4.	0.	-3.	-7.	-7.	10.	2.	12.	1.
1	22.80	3.	-15.	9.	-4.	5.	-4.	-19.	-18.	25.
1	24.25	16.	-7.	-7.	1.	-17.	10.	-17.	-4.	7.
2	22.80	-6.	-4.	17.	-8.	-12.	3.	-4.	7.	28.
2	24.25	-8.	26.	-5.	-12.	-8.	16.	9.	24.	26.
1	22.80	-7.	-10.	-6.	3.	4.	-10.	-24.	-7.	-2.
1	24.25	0.	-8.	7.	-10.	-2.	-2.	-7.	-5.	-3.
2	22.80	-10.	-4.	-5.	6.	-8.	-16.	-8.	-5.	-12.
2	24.25	-14.	-10.	-14.	-5.	-8.	-1.	-4.	-10.	-3.
1	22.80	14.	19.	13.	7.	14.	6.	15.	26.	12.
1	24.25	7.	18.	23.	22.	27.	18.	18.	13.	6.
2	22.80	31.	14.	19.	20.	25.	21.	27.	33.	24.
2	24.25	11.	15.	29.	20.	0.	12.	19.	17.	23.
1	22.80	11.	-14.	1.	-8.	-14.	0.	20.	-15.	-1.
1	24.25	2.	-14.	-18.	-6.	1.	-10.	0.	-15.	-2.
2	22.80	23.	-5.	-6.	19.	5.	16.	26.	1.	31.
2	24.25	5.	2.	-24.	15.	31.	33.	8.	15.	16.

			Above				Below			
		Control	Spatial Separation							
			2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
Trial	Length									
1	22.80	2.	3.	11.	-6.	14.	-7.	8.	5.	4.
1	24.25	20.	5.	-1.	-6.	7.	24.	-9.	8.	4.
2	22.80	14.	-1.	9.	15.	6.	-6.	-4.	14.	-1.
2	24.25	-3.	13.	1.	20.	14.	12.	1.	4.	9.
1	22.80	0.	-7.	11.	4.	7.	7.	-5.	-6.	8.
1	24.25	11.	12.	1.	5.	-2.	15.	20.	10.	-1.
2	22.80	7.	2.	2.	10.	17.	13.	1.	-1.	1.
2	24.25	19.	15.	9.	8.	1.	2.	-5.	22.	4.
1	22.80	14.	-5.	7.	21.	9.	19.	-7.	2.	-1.
1	24.25	6.	15.	10.	9.	21.	14.	2.	8.	11.
2	22.80	3.	-1.	10.	-1.	4.	4.	-5.	4.	-2.
2	24.25	7.	-1.	2.	9.	10.	0.	5.	8.	14.
1	22.80	5.	1.	-14.	5.	1.	0.	-12.	11.	1.
1	24.25	13.	-12.	-17.	-5.	14.	1.	-8.	18.	5.
2	22.80	16.	-2.	4.	-12.	-2.	-5.	-10.	0.	8.
2	24.25	6.	5.	7.	8.	16.	0.	8.	2.	2.
1	22.80	15.	-9.	-2.	3.	11.	-4.	18.	15.	9.
1	24.25	4.	17.	9.	7.	4.	11.	18.	1.	19.
2	22.80	8.	11.	5.	5.	4.	14.	19.	14.	6.
2	24.25	5.	18.	10.	1.	13.	29.	18.	12.	26.

			Above				Below			
		Control	Spatial Separation							
			2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
Trial	Length									
1	22.80	12.	12.	-8.	-5.	1.	14.	-8.	-4.	13.
1	24.25	15.	-8.	2.	-13.	-8.	29.	-5.	16.	1.
2	22.80	21.	16.	21.	6.	21.	15.	18.	30.	12.
2	24.25	15.	4.	1.	8.	12.	15.	28.	21.	15.
1	22.80	7.	13.	6.	13.	11.	6.	7.	14.	14.
1	24.25	12.	2.	10.	15.	8.	8.	11.	15.	9.
2	22.80	8.	17.	13.	5.	5.	15.	18.	10.	22.
2	24.25	11.	15.	18.	11.	12.	15.	15.	17.	12.
1	22.80	3.	-8.	-4.	3.	11.	10.	10.	3.	5.
1	24.25	5.	2.	-4.	-2.	-1.	16.	6.	-3.	8.
2	22.80	9.	-5.	-8.	9.	1.	5.	21.	4.	-4.
2	24.25	7.	1.	1.	-14.	2.	11.	-3.	15.	7.
1	22.80	-2.	5.	-1.	-1.	-3.	7.	7.	7.	-3.
1	24.25	9.	7.	13.	-2.	6.	16.	12.	1.	-2.
2	22.80	9.	3.	8.	-6.	12.	10.	3.	3.	9.
2	24.25	-4.	12.	8.	-1.	-2.	6.	6.	8.	17.

Experiment III

			Above				Below			
		Control	Spatial Separation							
			2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
Trial	Length									
1	63.40	0.	-12.	-8.	-10.	-6.	-3.	-5.	-10.	7.
1	75.00	-6.	-4.	-4.	-10.	-14.	5.	-17.	-17.	-6.
2	63.40	-21.	-8.	-11.	-18.	-6.	-14.	-13.	-10.	-18.
2	75.00	-6.	-7.	-16.	-11.	-11.	-18.	-12.	-22.	-20.
1	63.40	8.	-1.	6.	10.	10.	2.	2.	5.	4.
1	75.00	14.	2.	7.	9.	5.	4.	1.	7.	11.
2	63.40	7.	6.	1.	8.	4.	6.	8.	6.	8.
2	75.00	6.	0.	5.	8.	12.	3.	4.	-1.	5.
1	63.40	-10.	-24.	-2.	-16.	-22.	-1.	-3.	-11.	-10.
1	75.00	-13.	-18.	-34.	-9.	-15.	1.	-21.	-5.	-1.
2	63.40	-18.	-5.	-13.	-5.	18.	-2.	-20.	-26.	-30.
2	75.00	-6.	-23.	-18.	-10.	-5.	-16.	-19.	-3.	-15.
1	63.40	6.	9.	10.	8.	2.	-2.	8.	3.	14.
1	75.00	6.	3.	5.	15.	15.	3.	1.	1.	12.
2	63.40	-9.	-3.	7.	14.	1.	3.	0.	2.	-4.
2	75.00	11.	6.	3.	9.	3.	8.	9.	-2.	14.
1	63.40	15.	10.	7.	7.	4.	-5.	-9.	-5.	20.
1	75.00	16.	17.	8.	14.	24.	3.	3.	9.	0.
2	63.40	20.	6.	7.	13.	9.	3.	-3.	6.	15.
2	75.00	5.	1.	6.	14.	7.	9.	2.	16.	3.
1	63.40	-23.	2.	2.	5.	-9.	1.	7.	7.	8.
1	75.00	-8.	8.	7.	5.	0.	13.	3.	0.	-1.
2	63.40	8.	22.	8.	19.	1.	5.	-2.	2.	-2.
2	75.00	-5.	9.	-6.	14.	-4.	18.	4.	-5.	10.

			Above				Below			
		Control	Spatial Separation							
			2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
Trial	Length									
1	63.40	10.	9.	9.	21.	20.	-5.	3.	16.	0.
1	75.00	9.	5.	23.	20.	7.	6.	-5.	1.	7.
2	63.40	6.	17.	30.	21.	12.	19.	17.	41.	-1.
2	75.00	8.	21.	20.	24.	25.	-1.	20.	10.	14.
1	63.40	-6.	7.	-8.	-4.	-9.	-23.	-18.	10.	-2.
1	75.00	-5.	-7.	-3.	2.	-4.	-14.	-17.	-3.	2.
2	63.40	1.	-2.	-12.	14.	6.	-9.	-5.	-6.	-3.
2	75.00	-12.	-9.	0.	7.	-12.	-19.	-11.	-4.	13.
1	63.40	9.	9.	12.	17.	18.	12.	14.	-7.	6.
1	75.00	7.	5.	10.	4.	7.	3.	-7.	3.	12.
2	63.40	2.	8.	11.	15.	23.	32.	6.	12.	16.
2	75.00	10.	2.	18.	11.	-7.	20.	7.	21.	18.
1	63.40	7.	4.	4.	-2.	2.	-3.	-3.	-3.	0.
1	75.00	4.	-2.	6.	1.	1.	-1.	0.	1.	4.
2	63.40	-2.	1.	7.	-2.	1.	5.	5.	-4.	-4.
2	75.00	-1.	-3.	2.	6.	5.	0.	1.	6.	-3.
1	63.40	11.	-2.	5.	12.	8.	8.	10.	14.	0.
1	75.00	2.	9.	28.	22.	27.	9.	-5.	8.	2.
2	63.40	15.	11.	3.	17.	12.	15.	6.	3.	28.
2	75.00	8.	6.	20.	22.	15.	16.	-1.	18.	20.
1	63.40	7.	12.	-3.	20.	18.	12.	2.	5.	-1.
1	75.00	-7.	22.	-6.	10.	8.	11.	25.	0.	-7.
2	63.40	15.	13.	26.	20.	-6.	14.	17.	2.	13.
2	75.00	18.	-5.	15.	6.	11.	11.	17.	20.	10.

			Above				Below			
		Control	Spatial Separation							
			2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
Trial	Length									
1	63.40	12.	5.	20.	23.	18.	13.	4.	20.	13.
1	75.00	18.	17.	7.	17.	14.	24.	15.	20.	22.
2	63.40	8.	10.	24.	6.	16.	3.	6.	-5.	-6.
2	75.00	5.	7.	8.	26.	-5.	-7.	1.	17.	1.
1	63.40	12.	10.	15.	3.	2.	8.	1.	3.	-3.
1	75.00	16.	3.	-3.	16.	13.	-5.	-4.	8.	-1.
2	63.40	4.	8.	11.	9.	-4.	10.	5.	7.	2.
2	75.00	3.	18.	2.	-7.	1.	10.	-10.	0.	-8.
1	63.40	-7.	6.	15.	-1.	-1.	12.	6.	17.	1.
1	75.00	-12.	16.	2.	-8.	5.	0.	3.	1.	-5.
2	63.40	0.	20.	11.	6.	2.	4.	9.	13.	-1.
2	75.00	-5.	3.	2.	0.	2.	13.	4.	-2.	10.
1	63.40	-6.	1.	8.	1.	1.	-4.	-5.	-7.	-1.
1	75.00	-1.	-5.	0.	-4.	-8.	8.	-8.	-1.	0.
2	63.40	-10.	-1.	-2.	-7.	-10.	-2.	0.	1.	2.
2	75.00	0.	-6.	-3.	-3.	-1.	0.	-3.	-3.	0.
1	63.40	1.	-1.	1.	-6.	-2.	2.	3.	-5.	-4.
1	75.00	-9.	3.	10.	-6.	1.	11.	-9.	-7.	5.
2	63.40	-5.	-4.	-3.	0.	10.	-8.	-6.	-4.	-2.
2	75.00	-4.	-3.	4.	-3.	3.	-2.	-3.	-3.	-2.
1	63.40	8.	0.	2.	-1.	5.	-7.	-10.	-3.	-7.
1	75.00	5.	7.	13.	16.	15.	-5.	-4.	-4.	5.
2	63.40	-2.	4.	12.	8.	11.	2.	-8.	15.	2.
2	75.00	8.	9.	8.	12.	-3.	-6.	-5.	4.	13.

			Above				Below			
		Control	Spatial Separation							
			2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
Trial	Length									
1	63.40	-2.	21.	11.	12.	3.	22.	2.	8.	3.
1	75.00	1.	24.	4.	11.	5.	-1.	3.	-9.	1.
2	63.40	15.	8.	7.	17.	13.	5.	7.	7.	-2.
2	75.00	5.	14.	14.	12.	20.	3.	-5.	5.	-1.
1	63.40	5.	8.	12.	11.	14.	7.	-2.	-4.	-4.
1	75.00	-7.	1.	5.	13.	9.	-2.	6.	-2.	-7.
2	63.40	6.	8.	4.	0.	6.	2.	-2.	7.	3.
2	75.00	1.	11.	7.	8.	6.	-1.	1.	-6.	1.

Experiment IV

Position

Control	Above				Below			
Scores	2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
1.	0.	1.	1.	0.	1.	1.	0.	0.
0.	1.	0.	0.	1.	0.	0.	0.	1.
1.	1.	0.	1.	1.	1.	1.	0.	0.
1.	0.	1.	1.	0.	0.	1.	1.	1.
1.	0.	1.	1.	1.	1.	0.	0.	1.
1.	1.	0.	1.	1.	1.	1.	1.	1.
0.	0.	1.	1.	1.	0.	0.	1.	0.
0.	0.	0.	0.	0.	0.	0.	1.	1.
0.	0.	1.	0.	0.	0.	0.	1.	1.
0.	0.	0.	0.	0.	1.	0.	0.	0.
1.	0.	0.	0.	0.	1.	0.	1.	1.
0.	0.	0.	0.	1.	0.	1.	1.	1.
1.	0.	1.	1.	0.	0.	1.	1.	1.
0.	0.	0.	1.	1.	1.	0.	0.	1.
1.	1.	1.	0.	1.	1.	0.	1.	0.
1.	1.	1.	1.	1.	0.	0.	0.	1.
1.	1.	1.	1.	1.	0.	0.	0.	1.
1.	1.	1.	0.	0.	0.	1.	0.	1.
1.	0.	0.	0.	1.	0.	0.	1.	0.
1.	0.	0.	1.	1.	0.	0.	0.	1.
1.	0.	0.	0.	0.	0.	0.	0.	1.
0.	0.	0.	1.	1.	0.	0.	0.	0.
0.	0.	0.	0.	0.	1.	0.	0.	1.
0.	0.	0.	0.	1.	1.	0.	1.	0.

	Position							
Control	Above				Below			
Scores	2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
1.	1.	0.	1.	1.	0.	0.	0.	0.
0.	0.	1.	1.	1.	0.	0.	0.	1.
0.	0.	1.	1.	1.	0.	0.	0.	0.
0.	0.	0.	0.	1.	0.	0.	0.	1.
1.	0.	0.	1.	0.	0.	0.	1.	1.
1.	0.	0.	0.	1.	1.	0.	1.	1.
0.	0.	0.	0.	0.	1.	1.	0.	1.
0.	0.	0.	1.	0.	0.	0.	1.	0.
0.	0.	0.	0.	0.	1.	0.	1.	0.
1.	0.	0.	0.	1.	1.	1.	1.	1.
1.	0.	0.	1.	1.	1.	1.	1.	0.
1.	0.	0.	0.	0.	0.	0.	0.	0.
0.	0.	0.	0.	0.	0.	0.	0.	1.
0.	0.	0.	0.	0.	0.	1.	1.	0.
0.	0.	1.	0.	0.	0.	0.	0.	0.
1.	1.	1.	0.	1.	0.	1.	0.	0.
1.	1.	0.	1.	1.	0.	0.	0.	0.
1.	0.	0.	1.	0.	0.	0.	1.	0.
0.	0.	0.	1.	1.	0.	0.	0.	0.
0.	0.	0.	1.	1.	0.	0.	0.	1.
1.	0.	1.	0.	1.	1.	0.	0.	1.
0.	0.	1.	0.	1.	0.	1.	1.	1.
0.	0.	0.	0.	0.	1.	1.	0.	1.
0.	0.	0.	1.	0.	1.	1.	1.	1.

	Position							
Control	Above				Below			
Scores	2.1	4.2	8.4	14.7	2.1	4.2	8.4	14.7
1.	0.	1.	1.	1.	0.	0.	0.	0.
1.	1.	1.	1.	1.	1.	0.	1.	0.
1.	0.	1.	1.	1.	0.	1.	1.	1.
1.	1.	0.	1.	0.	0.	0.	0.	0.
1.	1.	1.	0.	0.	0.	0.	1.	0.
0.	0.	0.	1.	0.	1.	1.	1.	0.
0.	1.	0.	1.	0.	1.	1.	1.	1.
0.	0.	1.	1.	1.	1.	1.	1.	1.
0.	1.	1.	1.	1.	1.	1.	1.	1.
0.	1.	1.	1.	1.	1.	1.	1.	1.
0.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.
1.	1.	1.	1.	1.	1.	1.	1.	1.
0.	1.	1.	1.	0.	1.	1.	1.	0.
0.	0.	1.	0.	1.	1.	0.	1.	1.
0.	1.	0.	1.	0.	0.	0.	1.	1.
1.	1.	1.	1.	0.	1.	1.	0.	0.
0.	1.	0.	1.	0.	1.	0.	1.	1.
1.	1.	0.	1.	1.	0.	0.	0.	0.
1.	1.	0.	1.	1.	1.	1.	1.	1.
1.	0.	1.	1.	1.	1.	1.	1.	1.
1.	0.	1.	1.	1.	1.	1.	0.	0.

Experiment V

	Control		Contextual Length								
Spatial	Scores										
Separation	1	2	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
2.1	19.	0.	-8.	9.	5.	18.	14.	17.	12.	0.	-4.
8.4	1.	4.	0.	1.	-1.	5.	-1.	1.	7.	2.	-3.
14.7	3.	2.	-5.	-6.	-14.	6.	9.	0.	12.	-8.	6.
2.1	18.	11.	4.	22.	30.	49.	55.	36.	34.	19.	8.
8.4	8.	0.	29.	35.	26.	37.	39.	36.	27.	20.	25.
14.7	20.	10.	14.	9.	16.	15.	27.	25.	35.	6.	23.
2.1	-1.	-17.	11.	10.	23.	21.	6.	15.	9.	9.	-7.
8.4	8.	9.	24.	20.	18.	25.	14.	15.	10.	10.	10.
14.7	2.	3.	19.	12.	21.	26.	16.	17.	11.	7.	4.
2.1	-18.	-1.	-5.	13.	7.	21.	12.	6.	-2.	-2.	-5.
8.4	-14.	-5.	-13.	-2.	-13.	-5.	3.	8.	-9.	1.	-8.
14.7	-14.	-3.	-2.	4.	-5.	2.	-3.	-4.	-11.	-6.	-2.
2.1	2.	8.	-12.	-21.	7.	0.	25.	-4.	-8.	-8.	-18.
8.4	4.	-2.	-6.	5.	-5.	20.	4.	1.	-4.	0.	1.
14.7	-5.	0.	2.	10.	1.	2.	3.	-3.	-3.	6.	4.
2.1	5.	0.	-10.	-1.	12.	8.	32.	26.	3.	13.	12.
8.4	7.	5.	-3.	18.	-3.	39.	19.	18.	19.	16.	24.
14.7	8.	9.	6.	8.	14.	26.	25.	21.	21.	22.	8.
2.1	1.	5.	15.	33.	36.	26.	30.	33.	23.	22.	19.
8.4	-1.	18.	23.	24.	20.	18.	12.	17.	22.	16.	12.
14.7	4.	11.	-3.	7.	1.	22.	20.	3.	4.	11.	21.

	Control		Contextual Length								
Spatial	Scores										
Separation	1	2	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
2.1	5.	-1.	18.	17.	19.	22.	22.	13.	1.	-5.	-3.
8.4	-2.	12.	8.	7.	-4.	2.	12.	5.	11.	7.	8.
14.7	0.	4.	-8.	-1.	-4.	1.	8.	-3.	5.	10.	-5.
2.1	0.	0.	-17.	-5.	0.	-6.	-9.	-8.	-9.	-13.	-6.
8.4	9.	-3.	9.	7.	12.	7.	11.	-1.	9.	8.	3.
14.7	1.	-4.	-1.	-1.	-5.	-5.	-12.	1.	-15.	-8.	-12.
2.1	-4.	8.	-11.	1.	9.	18.	19.	22.	18.	2.	-11.
8.4	16.	-7.	-1.	2.	5.	16.	9.	34.	21.	18.	28.
14.7	8.	6.	-16.	5.	3.	25.	4.	19.	2.	8.	15.
2.1	-11.	-6.	-10.	-3.	8.	-7.	-18.	-30.	-24.	-28.	-1.
8.4	-9.	3.	3.	12.	8.	9.	10.	13.	-6.	-10.	-4.
14.7	-5.	5.	0.	-2.	-3.	-20.	3.	-14.	-14.	0.	-3.
2.1	10.	-4.	8.	2.	-16.	3.	5.	3.	-7.	-7.	-2.
8.4	-7.	0.	3.	-13.	5.	3.	0.	0.	0.	9.	1.
14.7	-7.	-2.	1.	-7.	8.	-3.	4.	7.	-2.	2.	5.
2.1	7.	4.	-4.	5.	28.	28.	19.	4.	19.	26.	9.
8.4	5.	13.	-12.	5.	29.	0.	21.	19.	27.	20.	11.
14.7	5.	18.	10.	36.	13.	8.	17.	21.	18.	4.	3.
2.1	3.	-7.	7.	20.	23.	22.	10.	13.	9.	8.	4.
8.4	-3.	1.	5.	10.	17.	25.	17.	11.	-3.	-3.	0.
14.7	-4.	7.	-3.	4.	8.	16.	12.	-4.	4.	-1.	13.

Spatial Separation	Control Scores		Contextual Length								
	1	2	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
2.1	-7.	-15.	1.	23.	12.	4.	-4.	-10.	-12.	-16.	-19.
8.4	-5.	-13.	8.	1.	3.	12.	4.	1.	-13.	5.	-5.
14.7	-6.	-6.	3.	5.	2.	-1.	-3.	4.	-9.	-2.	-11.
2.1	1.	1.	-4.	7.	9.	5.	7.	3.	-2.	1.	-5.
8.4	6.	-5.	7.	7.	15.	10.	-5.	0.	-5.	7.	1.
14.7	6.	2.	-9.	-4.	3.	-2.	-3.	3.	-5.	-2.	-2.
2.1	9.	29.	6.	35.	38.	43.	40.	35.	42.	25.	34.
8.4	34.	24.	43.	31.	50.	38.	70.	44.	48.	33.	53.
14.7	17.	12.	6.	25.	44.	32.	28.	40.	31.	53.	49.
2.1	15.	3.	-7.	6.	11.	4.	21.	20.	6.	25.	-6.
8.4	-5.	-4.	4.	8.	2.	21.	12.	11.	2.	8.	13.
14.7	6.	-1.	2.	-3.	1.	40.	11.	7.	8.	8.	4.
2.1	12.	6.	18.	7.	23.	22.	8.	6.	14.	14.	1.
8.4	1.	1.	9.	14.	11.	12.	3.	11.	8.	12.	0.
14.7	1.	6.	-13.	-1.	2.	2.	5.	1.	21.	-3.	4.
2.1	-16.	11.	-11.	-13.	10.	10.	-7.	5.	-1.	10.	4.
8.4	-2.	-17.	-6.	2.	-5.	12.	0.	-4.	-10.	-6.	-9.
14.7	-3.	-16.	-4.	4.	-15.	1.	3.	2.	-7.	2.	-12.
2.1	5.	0.	-19.	-11.	10.	2.	7.	12.	7.	-1.	-10.
8.4	19.	4.	1.	8.	-1.	22.	12.	20.	22.	5.	10.
14.7	6.	-7.	-1.	6.	15.	17.	12.	11.	18.	3.	10.

	Control Scores		Contextual Length								
Spatial Separation	1	2	22.80	24.25	27.15	31.50	37.30	45.55	53.25	63.40	75.00
2.1	2.	2.	21.	-15.	3.	-12.	0.	11.	4.	0.	-6.
8.4	-4.	-6.	-12.	4.	-14.	8.	9.	14.	1.	23.	11.
14.7	0.	3.	1.	-1.	-8.	1.	4.	19.	4.	14.	6.
2.1	-1.	8.	7.	6.	23.	19.	32.	28.	20.	13.	1.
8.4	2.	-2.	13.	4.	0.	6.	23.	4.	12.	2.	17.
14.7	3.	-2.	9.	5.	7.	15.	12.	14.	15.	6.	13.
2.1	0.	-8.	-4.	1.	-2.	14.	12.	-6.	13.	-2.	-12.
8.4	-4.	-6.	-7.	-13.	-12.	10.	9.	8.	21.	6.	-9.
14.7	-1.	-3.	-1.	10.	7.	12.	24.	12.	8.	16.	8.

Appendix C

Analysis of Variance Summary Tables on Illusion Scores

Analysis of Variance Summary Table of Illusion Scores in Experiment I

Source	SS	df	MS	F	df
Position (P)	2174.45	1	2174.45	10.04	
Error	5631.24	25	216.59		
Separation (S)	1100.01	3	366.67	4.52	1
Error	6328.85	78	81.14		26
P X S	158.62	3	52.87	1.07	1
Error	3855.46	78	49.43		26
Length (L)	35439.24	8	4429.91	10.24	1
Error	89971.29	208	432.55		26
P X L	3206.55	8	400.82	7.66	1
Error	10886.26	208	52.34		26
S X L	5309.73	24	221.24	4.75	1
Error	29038.41	624	46.55		26
P X S X L	1922.27	24	80.09	1.65	1
Error	30353.15	624	48.64		26

1. Degrees of freedom used in conventional analysis.
2. Degrees of freedom used with the Geisser-Greenhouse Technique.

Analysis of Variance Summary Table for Illusion Scores in Experiment II

Source	df	SS	MS	F
Trials (T)	1	433.95	433.95	1.19
Error	19	6934.02	364.95	
Length (L)	1	1058.33	1058.33	15.21
Error	19			
T X L	1	40.50	40.50	0.59
Error	19	1313.47	69.13	
Position (P)	1	2979.94	2979.94	8.87
Error	19	6381.80	335.88	
T X P	1	0.83	0.83	0.01
Error	19	3105.02	163.42	
L X P	1	87.76	87.76	1.48
Error	19	1125.45	59.23	
T X L X P	1	6.20	6.20	0.14
Error	19	854.89	44.99	
Separation	3	557.72	185.91	3.53
Error	57	2998.66	52.60	
T X S	3	47.87	15.96	.21
Error	57	4249.79	74.56	
L X S	3	362.22	120.74	1.27
Error	57	5426.31	95.20	
T X L X S	3	122.89	40.96	1.20
Error	57	1950.26	34.22	
P X S	3	302.09	100.99	1.02
Error	57	5639.93	98.95	
T X P X S	3	132.74	44.25	.60
Error	57	4221.04	74.05	
L X P X S	3	58.48	19.49	.29
Error	57	3831.43	67.22	
T X L P X S	3	49.44	16.48	.26
Error	57	3601.59	63.19	

Analysis of Variance Summary Table for Illusions Scores in Experiment III

Source	df	SS	MS	F
Trials (T)	1	58.20	58.20	.45
Error	19	2450.20	128.96	
Length (L)	1	43.58	43.58	.84
Error	19	987.45	51.97	
T X L	1	65.66	65.66	2.84
Error	19	431.12	22.69	
Position (P)	1	1699.76	1699.76	18.69
Error	19	1727.52	90.92	
T X P	1	14.10	14.10	.12
Error	19	2181.18	114.80	
L X P	1	2.89	2.89	.04
Error	19	1328.27	69.91	
T X L X P	1	116.45	116.45	2.28
Error	57	2681.28	47.04	
P X S	3	431.92	143.97	2.91
Error	57	2823.43	49.53	
T X P X S	3	3.40	1.13	0.02
Error	57	2911.94	51.09	
L X P X S	3	80.14	26.71	0.49
Error	57	3081.83	54.07	
T X L X P X S	3	71.05	23.68	.60
Error	57	2247.41	39.43	

Analysis of Variance Summary Table for Illusions Scores

in Experiment IV

Source	df	SS	MS	F
Position (P)	1	0.0023	0.0023	.01
Error	23	4.5260	0.1968	
Separation (S)	3	1.2223	0.3741	5.71
Error	69	4.5168	0.0655	
P X S	3	0.2525	0.0842	1.63
Error	69	3.5538	0.0515	

Analysis of Variance Summary Table for Illusion Scores in Experiment V

Source	df	SS	MS	F	df
Group (G)	5	4054.92	810.98	1.03	
Error	18	14173.21	787.40		
Separation (S)	2	1132.08	566.04	3.13	
S X G	10	2663.20	266.32	1.47	
Error	36	6509.23	180.82		
Length (L)	8	7285.27	910.66	10.51	1
L X G	40	4435.94	110.90	1.28	5
Error	144	12481.96	86.68		64
S X L	16	2647.56	165.47	2.78	1
S X G X L	80	4127.92	51.60	.87	5
Error	288	17163.14	59.59		18

1. df for conventional ANOVA.
2. df for Geisser-Greenhouse correction.