SOME THEORETICAL IMPLICATIONS REGARDING THE EFFECTS OF AGE AND PHYSICAL PARAMETERS ON THE DELBOEUF AND EBBINGHAUS ILLUSIONS

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ABSTRACT

On the basis of developmental trends, illusions have often been categorized as Type I, which increase with age, and Type II, which decrease. The Delboeuf and Ebbinghaus illusions have traditionally been assigned to these two categories, respectively. However, studies of developmental trends for these two illusions have yielded contradictory results.

Examination of the available studies suggests that they can be ordered systematically by supposing the following: (1) Type I and Type II illusions correspond to the categories of assimilation and contrast illusions; (2) given specific physical parameters and age levels, both the Delboeuf and Ebbinghaus illusions can become assimilation <u>or</u> contrast illusions; and (3) age trends for each illusion reflect the development of one underlying process--a tendency to shift from assimilative to contrast-based perception.

In the present study an attempt was made to find if these suppositions were correct by testing the hypotheses that (1) both assimilation and contrast forms of both illusions should occur; and (2) similar age trends for each illusion should occur. Children of ages five and one-half, seven and one-half or nine and one-half years inspected a series of Delboeuf and Ebbinghaus illusions whose inducing circle sizes were varied. Subjects adjusted a comparison circle to match the perceived size of a test circle.

Children of all ages showed the normal or positive form of the two illusions. Younger children showed a significant contrast or negative form of the Ebbinghaus illusion, and older children, a

non-significant tendency toward the contrast form of the Delboeuf illusion. These results partially supported the first hypothesis. However, no age trends were found. The latter result, which did not support the second hypothesis, was attributed to differences in methodology used in the present study as compared to that used in other studies.

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Finally my love to Krista who did not get to see her daddy and Pam who did not get to see her husband.

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CHAPTER I

INTRODUCTION

A Brief Overview

One of the areas that has always intrigued those concerned with man's functioning is how he perceives the world around him. Special interest has been focused on those percepts where the subjective judgement does not coincide with the objective parameters. These percepts have been categorized as illusions and encompass a large range of phenomena. It has been felt that if one could understand these apparent anomalies in perception, a fuller and more comprehensive understanding of the general processes of perception could be produced.

Optical geometric illusions are one of the sub-groups of illusions which have been extensively investigated. These illusions consist of a number of line drawings which produce subjective distortions of size, length, or symmetry. Part of the reason they have commanded such a large share of the research on illusions is that the illusory figures are easy to produce and that illusion production is highly reliable. Another reason for their extensive use may be the fact that Piaget (1942, 1969) has made these figures an integral part of his theory of perceptual development.

Piaget (1942, 1969) has suggested that there are basically two types of illusions which can be separated on the basis of their developmental trends. The amount of Type I illusion or primary illusion increases with age, while the amount of Type II illusion or secondary illusion decreases with age. However, the results for the developmental trends in illusions are contradictory and confusing (Wohlwill 1968). It is with this confusion that the present study is concerned. For a discussion of the developmental trends for a large variety of illusions see Wohlwill (1968). Of particular interest here are two physically similar forms of the Type I and Type II illusions, the Delboeuf and Ebbinghaus illusions, respectively.

The Delboeuf illusion is shown in Figure 1. It consists of a test (T) circle surrounded by a larger inducing (I) circle. The T circle is usually judged against a comparison (C) circle. In this case the T circle is judged larger than its physical size. That is, it is judged to be closer in size to the I circle than it is physically. This phenomenon has been referred to as assimilation (Pressey, 1967, 1971). Changing the size of the I circle changes the judged size of the T circle. If we make the I circle large enough the T circle is judged to be smaller than its actual size. When this happens the figure is often referred to as the "negative Delboeuf". That is, the distortion of the T circle size seems to be in the opposite direction to normal.

The Ebbinghaus illusion or Titchner Circles is shown in Figure 2. It consists of a T circle surrounded by a number of larger I circles. The T circle is judged against a C circle. In the standard illusion the T circle is judged as being smaller than its physical size. That is, it is judged as being further in size from the I circle's size than it is physically. Note that although the Delboeuf and Ebbinghaus illusions have common physical features,

Fig. 1. The Delboeuf Illusion:

_A_ the standard form,

_B_ the negative form.

A

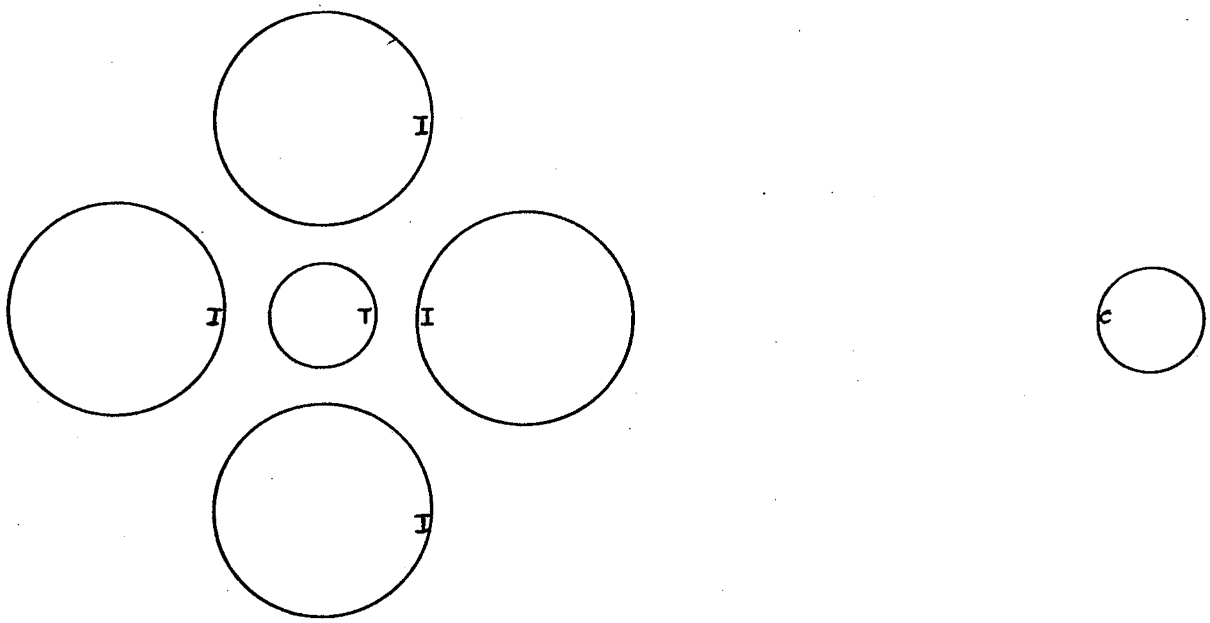
B

Fig. 2. The Ebbinghaus Illusion:

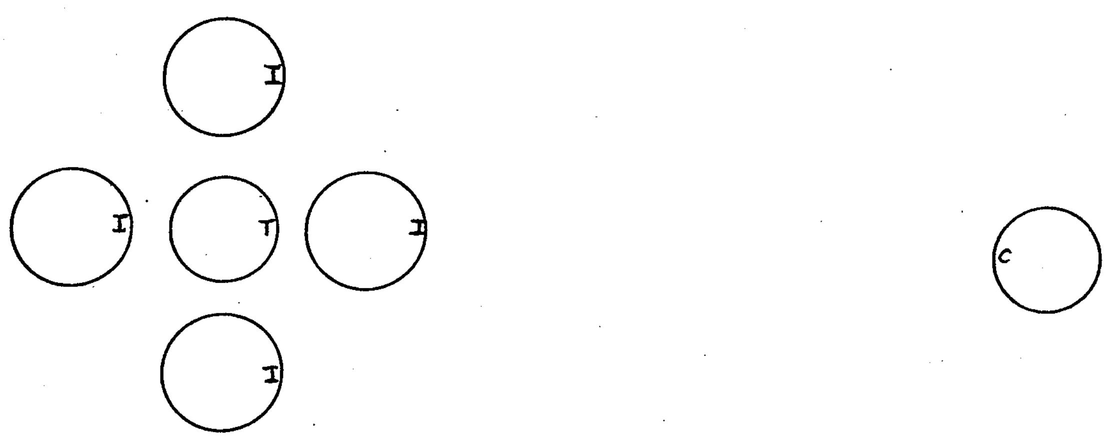
A the standard form

B the negative form.

A



B



the standard forms produce opposite effects on the judged size of the T circle.

Increasing the size of the I circle in the Ebbinghaus causes the illusory effect to increase in magnitude. There is some evidence that when the I circles are fractionally larger than the T circle young children will judge the T circle as being larger than it is physically. This effect does not appear in the judgements of adult subjects (Weintraub and Cooper, 1972). When it does occur in the judgements of young subjects it will be referred to as a negative Ebbinghaus illusion.

As pointed out earlier, there is considerable confusion in the literature with regard to developmental trends for illusions. Table 1 illustrates this point with respect to the Delboeuf and Ebbinghaus illusions. For example, with the standard Ebbinghaus two authors have found that the amount of illusion increases with age (Wapner and Werner, 1957; Weintraub and Cooper, 1972), while two other authors have found the amount of illusion to decrease with age (Russell, 1934; Sigurdson, 1972). For the positive Delboeuf illusion, where all the results are in the same direction, the amount of decrease in the illusion with age varies greatly among the studies.

A method which might help unravel the contradictions in the developmental studies is to consider a second classification system for illusions. The "Assimilation Theory of Illusions" (Pressey, 1967, 1971; Pressey et al., 1971) suggests that illusions can be classified as to the presence or absence of assimilation, of the

TABLE 1

Reported Age Effects for the Ebbinghaus and Delboeuf Illusions

TYPE OF AGE EFFECT

ILLUSION TYPE		Increase with age	No change	Decrease with age
DELBOEUF	Positive (assimilation)		Santostefano (1963)	Piaget (1942) Weintraub and Cooper (1972) Sigurdson (1972)
DELBOEUF	Negative (contrast)	Santostefano (1963)		Piaget (1942)
EBBINGHAUS	Positive (contrast)	Wapner and Werner (1957) Weintraub and Cooper (1972)	Russell (1934)	Sigurdson (1972)
EBBINGHAUS	Negative (assimilation)			Weintraub and Cooper (1972)

element to be judged, towards the inducing portion of the figure. In the case of the Delboeuf, when the T circle is judged to be closer in size to the I circle it is an assimilation illusion. When the reverse happens, that is, where the T circle is judged further in size from the I circle (smaller) than it really is, the illusion is classified as a contrast illusion. The Ebbinghaus falls into this category of illusion. Although the standard form of the Ebbinghaus is a contrast illusion, the negative form of the illusion is an assimilation illusion.

The categories of Type I and Type II illusions closely match the categories of assimilation and contrast illusions, respectively. It may be that when the I circle is changed to produce a negative Delboeuf, a developmentally different type of illusion is present. This would in part explain some of the confusing results.

Now suppose that each of the Type I and Type II illusions contain some Type I characteristics and some Type II characteristics at all times, but that one of the characteristics predominates. As we change the I circle size we change the relative amounts of Type I and Type II characteristics. We can expect apparently different developmental trends for the amount of illusion with different parameters of I circle size and subject's age.

This is exactly what was hypothesized in the present study. It was thought that the divergent results in the area can be explained by looking at the developmental trends as a function of age, the basic type of illusion, and the parameters used to produce that illusion. It was hypothesized that systematically varying these parameters would produce a clear series of developmental trends for the Delboeuf and Ebbinghaus illusions.

To understand fully the rationale and implications of the present study, it is necessary to review the relevant literature in the area. A discussion of the theoretical basis for both the developmental theories of illusions and the assimilation theory of illusions are presented first in order to provide an understanding of the theoretical frameworks used in developmental studies of illusions.

Following this are separate sections on the Delboeuf and Ebbinghaus illusions. In each section the parameters which affect the illusions are considered first. This provides an understanding of the range of stimuli being used in the developmental studies. Finally, the evidence presently available on developmental trends for both positive and negative forms of the illusions is presented. This is followed by an integration of the data presented in the previous sections and the rationale for the present study.

Developmental Differentiation of Optical Geometric Illusions

Binet (1895) carried out a study on the developmental changes in the Muller-Lyer illusion (Figure 1.1, Appendix 1). Using the method of constant stimulus he measured the amount of illusion for 60 children of nine years, and 45 children of 12 years. He found that the illusion decreased with increasing age. In his discussion of the findings he cited previous data which suggested that the size-weight illusion increased with age (Dressler, 1894). This led him to the conclusion that illusions could be classified into two groups on the basis of whether they increased or decreased with age. He further suggested that those which decreased with age such as the Muller-Lyer "are innate" while those that increased with age "are acquired".

Binet's concept of two distinct groups of illusions which could be separated by their developmental trends generated little research until Piaget (1942, 1969) began to reconsider the developmental properties of illusions. A study of the developmental trends for several illusions by Piaget (1942) supported Binet's concept of two developmentally distinct groups of illusions. Piaget, however, rejected Binet's concept that these illusion groups are innate and acquired. He alternatively suggested that Binet's "innate" group should be classified as "primary" (Type I) illusions, while his "acquired" group should be classified as "secondary" (Type II) illusions.

Some of the common Type I geometric illusions showing a decrease with age include the Muller-Lyer, Delboeuf, and the Sander Parallelogram. These three illusions are represented in Appendix 1 (Figure 1.1, Figure 1.2, and Figure 1.3, respectively). The Type II illusions are not as well represented among the optical geometric illusions but a few do show the standard increase in magnitude with age. These include the Oppol-Kundt and the Ebbinghaus which are represented in Appendix 2 (Figure 2.1 and Figure 2.2, respectively).

Piaget's choice of "primary" and "secondary" to express the two developmental groups of illusions, was based on what he felt are the underlying processes involved in the developmental changes. He felt that the primary illusions (which decrease with age) are viewed as "a single field effect" (Piaget, 1969, p. 3). That is, the illusion occurs because the figure is judged as a single unit and not as discrete parts. Support for this assumption was supplied by Piaget's studies which showed that the magnitude of primary illusions remained unaffected when presented for short periods of time in a Tachistoscope (T-scope). The time of presentation was so short that no visual exploration could occur. Piaget (1949, p. 14) defined the phenomenon, of "T-scope presentation of the stimuli .... which prevent visual exploration" as centration. Piaget (1969) also found that secondary illusions dissipated when they were presented in a T-scope. This led him to conclude that secondary illusions increase with age due to age-related increases in visual exploration and "couplings" (Piaget 1969, p. 69).

Piaget (1969) supported his concept of changes in centration and decentration with age by studying developmental changes in size of field of view and in subject's ability to concentrate on discrete visual area. He found that six year old children have a larger field of view (18.5 mm x 50.7 mm) than do adults (10.1 x 31.6 mm) when viewing a number of figures, such as verticals, horizontals and obliques. He further found that children cannot fixate on a given point for more than a very small fraction of a second while an adult can fixate for several seconds (Piaget, 1969, p. 138). These behaviours were taken to indicate that the child, due to his inability to fixate, combined with a tendency to attend to a large field, perceives figures wholistically. The adult, or older child who no longer utilizes this wholistic ability, view figures as discrete elements. This, for Piaget, explained why primary illusions decrease with age. That is, the wholistic type of percept, which Piaget assumed to be the basis of primary illusions, decreases with age. He further suggested that "a quantitative diminution of primary illusions .... are, indirect causes for fresh (secondary) illusions" (Piaget, 1969, p. 137). Although Piaget suggested that two processes function as the basis for the two illusion groups, he did not explain how they are related. He also did not state if the two processes can occur in the same illusion simultaneously. Although he did not deal with this question directly it may be inferred from his writings (Piaget, 1969) that he perceived the processes to be mutually exclusive and dependent on the figure being viewed.

A second system for describing illusions, which is relevant to the Delboeuf and Ebbinghaus illusions, is to classify the illusion by whether the element judged (T circle) is seen as being closer to (assimilation) or further from (contrast) its context (I circle). Until recently, this method has been purely descriptive. This descriptive dichotomy between assimilation illusions and contrast illusions has formed the basis for a sophisticated predictive theory of illusions (Pressey, 1967, 1971; Pressey _et al._, 1971). The theory makes the basic assumtion that an element such as the T circle is judged with respect to the other elements around it. In the case of the Delboeuf the T circle is judged as if it were on a set of circles, with itself and the I circle defining the two extremes of the set. Since the T circle is at the one extreme, the judgement of it is affected by the "tendency to the mean".

The Ebbinghaus illusion can also be thought of as a series of circles with the I and T circles defining the extremes. In this case, however, assimilation does not occur. Instead of producing a tendency to the mean the T circle is judged to be further from the mean in size than it is physically. The interesting fact about this method of classification is that the assimilation category closely matches Piaget's primary illusion category, while the contrast category matches the secondary category. It would be helpful to study what happens to the developmental trends of an assimilation illusion if it were to become a contrast illusion since it may developmentally behave as a Type I illusion.

The Delboeuf Illusion

Physical parameters affecting the Delboeuf Illusion. In order to understand the results from developmental studies of the Delboeuf, it is necessary to understand the effects of different parameters on the illusion, since different developmental studies have used varying illusion parameters.

The standard Delboeuf illusion (Figure I) consists of a T circle with an I circle which either surrounds the T circle or is inside the T circle. The T circle is judged against a C circle. The T circle is judged to be larger than its physical size when surrounded by a larger I circle.

Piaget et al., (1942) studied the effect of changing I circle size on the perceived size of the T circle. They used five T circle radii (9, 12, 15, 18 or 36 mm) while the I circle ranged from the same size as the T circle to 75 mm in one mm steps. Subjects judged the T circle against a single paired C circle. The authors used "about 100 children" in four age groups (5-6 years, 7-8 years, and 10-12 years) and a group of 30 adults. The results showed that an increase in the I circle size led to an initial increase in the perceived size of the T circle. A further increase of the I circle produced a decrease in the illusion until the illusion became negative. That is, as the I circle expanded beyond a certain point the assimilation effect on the T circle decreased and a contrast illusion was finally produced. Piaget et al., (1942) also found that the magnitude of changes in the illusion, produced by changes in the I circle size, decreased with age; however, the shape of the curve for amount of illusion as a function of the I circle size reamined the same between ages. From these results Piaget produced a predictive formula for the amount of illusion as a function of an I/T circle size ratio.

Keats (1964) used the method of paired comparisons to validate Piaget's formula for the Delboeuf illusion. He used a T circle of 1 1/32 ins. in diameter and had I circles of 9/8, 5/4, 3/2, 2, 3, and 4 times greater than the T circle. His stimuli can be thought of as a series of I circle size to T circle size ratios (I/T ratio). This allowed comparison of illusions using different T circle sizes.

Each of his I/T combinations was presented with a comparison circle circle ranging from 7/8 to $1\frac{1}{4}$ ins. in diameter by 1/12 in. steps. Presentation of the 42 stimuli, one card for each possible combination, was done in random order. The subject simply had to state whether the T or C circle was larger. A group of 64 adults was used. The case in which the I circle was two and four times larger than the T circle a reversal of the illusion was obtained (contrast). The maximum illusion was found at an I/T ratio of 3/2 as predicted by the formula. The fit with the predicted curve was fair. Keats suggested that this poor fit was partially due to the large steps in size of the C circle and suggested that use of smaller C circle steps would refine the fit.

These findings were supported in a study by Ikeda and Ohonai (1955). Using the paired comparison technique they presented stimuli in a T-scope for $\frac{1}{2}$ sec. duration. Using five college students they obtained six estimates per subject for each stimulus configuration (T = 30 mm, I = 10, 15, 20, 40, 60 or 80 mm, C = 22 to 36 mm in 1 mm steps). In the case where I was twice as large as T, an assimilation illusion was found but when an I/T ratio of 8/3 was used, a contrast effect similar to that found by Keats (1964) was obtained. A contrast effect was also found for an I/T ratio of 3/1. They further found that a more or less symmetrical function developed on either side of the point where I = T. Thus it appears that a contrast illusion can be obtained using the Delboeuf figure if a large enough I circle is used. The finding of a maximal illusory effect occurring at an I/T ratio of

3/2 has been replicated by Weintraub et al., (1969), Ikeda and Obonai (1955) and Weintraub and Cooper (1972).

This maximal value of 3/2 also occurred in a study of the Delboeuf illusion performed by Morinaga (1935, cited in Oyama, 1960), who further found that an I/T circle ratio of 5 or 6 to 1 produces a contrast effect. Morinaga moved the I circle's centre in steps away from the T circle until the circumferences of the two circles just touched. He found a general decrease in the assimilation effect and the eventual production of a contrast illusion. The figure which produced a contrast illusion (the I circle beside the T circle) was in effect an Ebbinghaus illusion with only one I circle.

It is worth noting parenthetically that Weintraub et al., (1969) have performed several studies on the effects of figure contrast and of broken vs. solid lines for the I and T circles on illusory magnitude. Using the staircase method, described on page 18 of the present report, they found that reducing the luminous contrast, or breaking the lines of the I circle, caused a general decrease in the illusion over all I/T ratios. When the contrast of the T circle was decreased or its line was broken, a general decrease in the magnitude of the illusion occurred. This produced a contrast illusion with a smaller I/T ratio than normal (5/3 or 6/3). It appears that the judged size of the T circle is drawn closer to the physical size of the I or to the T circle depending upon which has the greater contrast or greater completion of lines. This effect decreases slightly with age (Weintraub and Cooper, 1972).

Developmental trends for the positive (assimilation) Delboeuf. The previously cited study by Piaget et al., (1942) is one of the first studies in which age changes in the Delboeuf illusion were examined. Piaget suggested that although the magnitude of the positive Delboeuf decreased with age, the function of the I circle size to amount of illusion produced remained constant between ages. This conclusion was based on simple inspection of the data.

Santostefano (1963) conducted an investigation of the developmental trend for the positive and negative Delboeuf illusions. He used two positive illusions having T circles of 9 and 18 mm and I circles of 12 and 25 mm respectively. He also used two negative forms of the Delboeuf having T circles of 9 and 18 mm radius but this time having I circles of radius 45 and 55 mm respectively. He used ten boys and ten girls in each of three age groups (6, 9 and 12 years). Each subject judged whether or not the T circle was larger than the C circle. C circles ranged from 7 to 12 mm in $\frac{1}{2}$ mm steps for the nine mm T; and from 16 to 21 mm, in $\frac{1}{2}$ mm steps, for the 12 mm T. He then scored the responses as follows: If the judgement was in the expected direction it was given a value of plus one for each $\frac{1}{2}$ mm beyond the actual T circle size, and was given a value of minus one for each $\frac{1}{2}$ mm step judged in the opposite from expected direction. For example, with a nine mm T circle and the 12 mm I circle a response of larger for the T circle with respect to a 10 mm C circle was given a value of minus two. He then collapsed the scores for both positive illusions (T = 9 and