ILLUSORY MODIFICATIONS OF AREA AND APPARENT LIGHTNESS.

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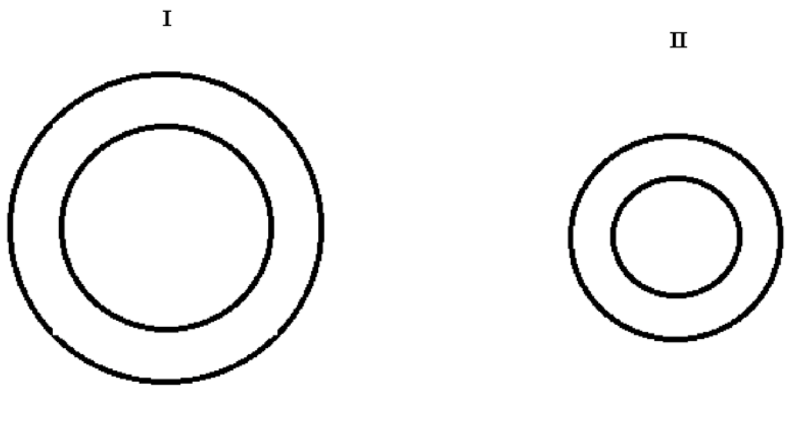
Abstract

A white disk when inside a small concentric circle (a display like Delboeuf figure) looks lighter than when surrounded by a larger one. The magnitude of the effect has been measured: PSE are reported for two different measures of the surrounding circle and three different grey backgrounds (EXP. 1a and b). The aim of a second experiment was to compare the increased lightness effect to the illusory size increment of the central area. Perceived area (EXP. 2a) and lightness magnitudes of a central white disk (diameter: 1.2 cm), surrounded by different circles (diameter: 3, 5, 7, 9 e 11 cm), on a middle grey background, were scaled, according to Pair Comparisons Method. The "distances" of the targets on "area" and "lightness" continua have been determined.

The aim of the present research was to check whether exquisitely phenomenal modifications of area affect perceived lightness, without any change in the luminance/reflectance of a surface. The Delboeuf illusion has been employed to alter the perceived size of a target. The complete Delboeuf pattern shows two pairs of concentric circles: when the diameter of the inner circle of the first figure geometrically matches the diameter of the outer circle of the second figure (Coren & Girgus, 1978), observers judge the inner circle of the first figure to be larger than the outer circle of the second figure. In this study the first part (I) only of the figure described by Delboeuf (1893) has been used (Piaget, 1961). Contemporary studies of the Delboeuf illusion use a single figure with two concentric circles and typically the inner one is judged (Jaeger & Long, 2007): "in current works on this illusion researchers compare a first circle without an outer paired circle with a second one with an additional outer paired circle" (Nicolas, 1995).

Fig. n. 1



The central circle surrounded by a concentric circumference (I) is overevaluated in respect to the same size circle II with a smaller circumference inscribed (Piaget, 1961).

The effect of lightness and lightness contrast on the magnitude of the illusion has been considered in previous researches: greater lightness contrast of the surrounding circle, relative to the central one, increases the overestimation of the central area (Oyama, 1962; Weintraub & Cooper, 1972; Sjostrom & Pollack, 1972). How the illusion affects the perceived lightness of the target, instead, has not been observed.

Experiment n. 1

A white disk, when inside a small concentric circle (a display like those originally proposed by Delboeuf, 1865), looks lighter than when surrounded by a larger one. In a preliminary experiment the magnitude of the effect has been measured for two different diameters of the surrounding circle and three different grey backgrounds.

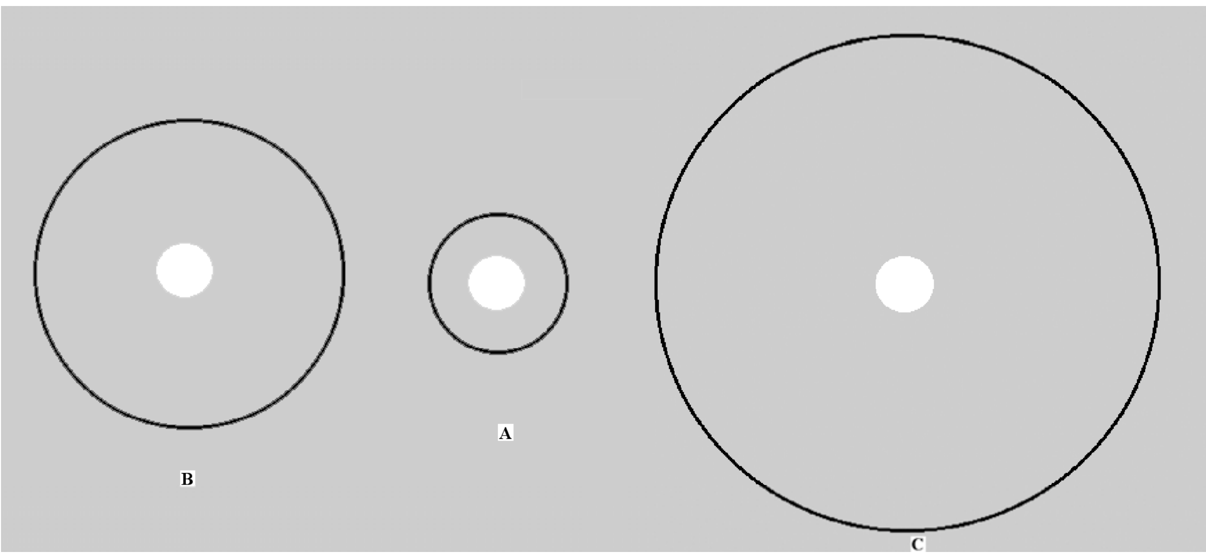
Method

A white disk, diameter 1,2 cm, surrounded by a 3 cm diameter circumference (A), had to be compared in lightness to a disk equal in size but surrounded by a 6.6 cm diameter (B) circumference (EXP. 1a) or by a 11 cm diameter (C) circumference of (EXP. 1b). Each pair of displays appeared on three different grey backgrounds (11.8, 5.42, 2,59 lumens/m2), on a monitor (Apple Cinema Display, 20 inch widescreen); repeated measures were taken across the three levels of background lightness (Winer, 1971).

Forty students, aging from 19 to 26 years (20 females and 20 males), took part to the experiment; all had normal or corrected to normal vision and were naive as to the purpose of the experiment. Twenty observers participated to the first session (EXP. 1a), comparing disks in A and in B; a different group fulfilled the second session (EXP. 1b), comparing A and C.

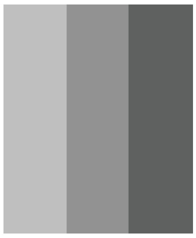
The luminance of the disk in display A was modified in 6 steps (2% each) to match the lightness of the disk in display B and display C (the initial intensity of all the disks was 30 lumens/m2). Stimuli were *tachistoscopically* presented at eye level; exposure time was 500 msec (Jaeger & Lorden, 1980) at 900 msec intervals, during which a central fixation point appeared on the grey background. Viewing distance was about 70 cm. Each display came into view random, both on left and on right, four times. The experiment was run in a nearly darkened room.

Fig. n. 2



Experimental displays of EXP. 1a e EXP. 1b

Fig. n. 3



*Levels of grey chosen as experimental backgrounds: (**1**)11.8,(**2**) 5.42, (**3**)2,59 lumens/m2.*

Results

The intensity of the disk inside the smaller circle must be reduced to make it look of the same lightness as the disk inside the larger one.

Table n. 1

EXP. 1a		
1	**2**	**3**
6.9	**7.8**	**7.9**
7.333 average		

Decrement in %, on a photoshop greyscale, of the disk inside the smaller circle (Display A) for the three different backgrounds (1, 2, 3), in order to phenomenally equal (PSE) the disk inside the larger circle (Display B)

EXP. 1b		
1	**2**	**3**
6.2	**5.7**	**7**
6.517 average		

Decrement in %, on a photoshop greyscale, of the disk inside the smaller circle (Display A) for the three different backgrounds (1, 2, 3), in order to phenomenally equal (PSE) the disk inside the larger circle (Display C)

The data *(PSE)* differ according to the two different sizes of the inducing circle (EXP. 1a/EXP. 1b: F_1 = 7.425, p = .0097) and the three different backgrounds (repeated measures: F_2 = 5.921, p = .0041). Interaction between the two variables tend to be significant: F_2 = 3.8, p = .0267. In order to match the luminance of disk B (EXP. 1a), disk A must range from 22.7 lumens/m_2 (maximum lowering 22.33%) to 23.4 lumens/m_2 (minimum lowering 22%), in order to match the lightness of disk C (EXP. 1b), disk A must range from 23.4 lumens/m_2 (max. 22.33%) to 25.5 lumens/m_2 (min. 15%).

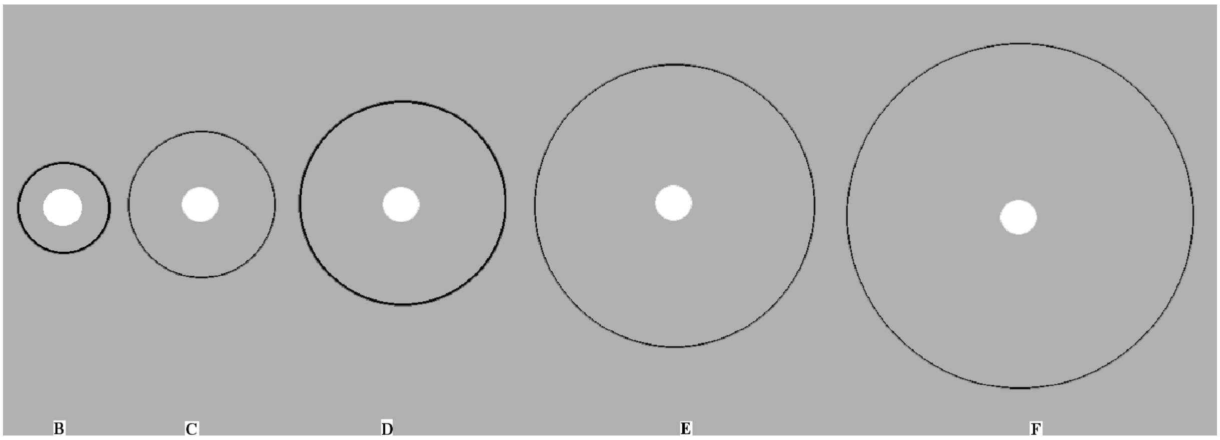
Experiment n. 2

The aim of the second experiment was to compare the illusory modifications of size of the inner disks to the changes in perceived lightness of the same targets.

Method

A series of five new displays (B, C, D, E, F), similar to the previous ones (inner disk diameter: 1,2 cm), has been prepared. The variable was the size of the inducing circles (diameters of the outer circumferences were: 3, 5, 7, 9 e 11 cm). The targets were shown in all possible pairs, four time each, according to the method of pair comparisons (Guilford, 1954).

Fig. n. 4



*Experimental displays, named **B, C, D, A, F,** presented in every possible pair.*

Thirty students (aging from 19 to 26) took part to the experiment and were assigned randomly to one of two groups. Fifteen observers (more females than males) were asked to evaluate the relative size of the white disks in each pair (they had to answer the question "which of the two disks is larger?"); judgments were of two categories (EXP. 2a).

A different group of fifteen observers had to evaluate the relative lightness of the white disks in each pair of the same displays (the question was "which of the two disks is lighter?"), no "equal" responses were accepted (EXP. 2b).

All the displays (30 lumens/m2) appeared on a grey background (5.37 lumens/m2); the experimental procedures (room, monitor, viewing distance, exposure times) were the same as in the previous experiment.

Results

The data obtained in the two different sessions (EXP. 2a and EXP. 2b) of the second experiment are respectively shown in table n. 2 and table n. 3. Raw answers have been transformed into percentages of "preferences" for one stimulus in each pair and subsequently into " scale separations matrices Z" in which any **z** score represents the distance between two displays (Torgerson, 1958). Obtained percentages do not differ from expected ones (in both cases $\chi 2$ values exhibit a probability of occurrence $.50 > p < .30$).

As reported in table n. 2, the perceived size of the inner white disk decreases with the increasing size of the diameter of the circumscribed circle: the smaller the outer circle is, the larger the inner disk appears. Disks lightness exhibits the same trend (table n. 3), although the effect seems less remarkable, many proportions being not far from 50%.

The data from the two different sessions have also been considered together. The two vectors of scale values $\mathbf{R}j$ (area and lightness) are highly correlated (r = .9385). Linear regression of the second scale (lightness) on the first one (area) yields a β coefficient of .477 (s.e.= .09). The coefficient is statistically significant at the 98% confidence level. Moreover, variation in the first scale explains approximately 88 % of the variation in the second scale. The two series show the existence of a powerful link between the two phenomenal attributes evaluated. The data are consistent with the hypothesis of a causal relationship between the stronger effect (enlargement) and the second one (enlightening).

Table. n. 2

	F	E	D	C	B
F	**.500**	**.700**	**.900**	**.967**	**.900**
E	**.300**	**.500**	**.717**	**.850**	**.834**
D	**.100**	**.280**	**.500**	**.700**	**.867**
C	**.134**	**.150**	**.300**	**.500**	**.900**
B	**.100**	**.167**	**.134**	**.100**	**.500**

	F	E	D	C	B
F		**.5244**	**1.2815**	**1.8384**	**1.2816**
E	**-.5244**		**.5828**	**1.0364**	**.9701**
D	**-1.2816**	**-.5828**		**.5244**	**1.1123**
C	**-1.8384**	**-1.0364**	**-.5244**		**1.2816**
B	**-1.2816**	**-.9701**	**-1.1123**	**-1.2816**	
Σ *zjk*	**-4.9262**	**-2.0649**	**.2277**	**2.1176**	**4.6456**
M *zjk*	**-.9852**	**-.4129**	**.0455**	**.4235**	**.9291**
R*j*	**.0000**	**.5723**	**1.0307**	**1.4087**	**1.9143**

Σ*zjk:* sums of the columns.
M*zjk*: average of the original matrix transformed in Z scores to represent the psychological distance on the magnitude continuum (Thurstone, 1927).
R*j*: scale values obtained by giving the value zero to the lowest stimulus in the list. The scale values can be considered as valid indices of the position occupied by the displays on the perceived size *continuum.*

Proportion matrix of the five disks judged in terms of perceived area.

Scale separation between pairs (matrix Z)

Table n. 3

	F	E	D	C	B
F	**.500**	**.634**	**.534**	**.767**	**.600**
E	**.366**	**.500**	**.550**	**.784**	**.700**
D	**.466**	**.450**	**.500**	**.634**	**.784**
C	**.233**	**.216**	**.366**	**.500**	**.750**
B	**.400**	**.300**	**.216**	**.250**	**.500**

	F	E	D	C	B
F		**.3425**	**.0853**	**.7290**	**.5533**
E	**-.3425**		**.1257**	**.7858**	**.5244**
D	**-.0853**	**-.1257**		**.3425**	**.7858**
C	**-.7290**	**-.7858**	**-.3425**		**.6745**
B	**-.5533**	**-.5244**	**-.7858**	**-.6745**	
Σ *zjk*	**-1.7101**	**-.1.0934**	**-.9173**	**1.1828**	**2.2380**
M *zjk*	**-.3420**	**-.2186**	**-.1834**	**.2365**	**.4476**
R*j*	**.0000**	**.1234**	**.1586**	**.5785**	**.7896**

Σ*zjk:* sums of the columns.
M*zjk*: average of the original matrix transformed in Z scores to represent the psychological distance on the lightness continuum (Thurstone, 1927).
R*j*: scale values obtained by giving the value zero to the lowest stimulus in the list. The scale values can be considered as valid indices of the position occupied by the displays on the perceived lightness continuum.

Proportion matrix of the five disks judged in terms of lightness.

Scale separation between pairs (matrix Z).

Discussion

The two experiments, taken together, although do not provide ultimate information, neither about perceived lightness in general, neither about Delboeuf illusion, allow some speculations about the two phenomena and request for further theoretical discussion and new experimental researches.

The increased lightness effect, connected to the illusorily extended area, is somewhat counterintuitive, being the same physical intensity diffused on a larger area. We can also hypothesize that the changes in lightness, varying along background luminance (EXP. 1a and EXP. 1b), are not determined by area enlargements but just concur with them (EXP. 2a and EXP. 2b)**,** or, perhaps, both the effects are affected by a third variable. As the magnitude of the Delboeuf illusion too varies with changes in the contrast between the figural elements and their background (Jaeger & Lorden, 1980), some interdependence between the two effects could be conceived. The observed lightness enhancements make propend for lower level (structural) mechanisms (Coren 1994), relying on sensory processes (Jaeger & Long, 2007), at the root of the classical Delboeuf effect.

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