OPPOSITENESS IN VISUALLY PERCEIVED FORMS

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Introduction

The experiments presented in this paper investigate the perceptual structure of oppositeness with reference to simple geometric figures.

The claim that relationships, and not only properties, are perceived just as directly as other aspects of a scene was a basic assertion in the theoretical foundations of Gestalt Psychology (Ehrenfels, 1890; Meinong, 1882). This premise was also at the heart of many experimental studies conducted in Gestalt Psychology (for a review, see Bianchi & Savardi, 2002).

Perceptual research has made very little progress in understanding what the *perceptual constraints* are in the recognition of relationships between various types of patterns (forms, sounds, movements etc**...**) since Goldmeier's pioneering investigation on the recognition of *Similarity in visually perceived forms* (1936/72). This work, later partially confirmed by Palmer's (1978) results, represents the most thorough contribution thus far to the study of perception of similarity in simple configurations in adults. More recent psychological literature has focused on the cognitive "rules" for the recognition of similarity and difference. This literature is for the most part derived from Tversky's (1977) contrast model (Medin Goldston, & Gentner,1990, 1993; Ritov, Gati, & Tversky, 1990; Sattath & Tversky, 1987; Tversky & Gati, 1982). Other research has focused on categorization processes (Nosofsky, 1988; Ross, 1989; Ross & Kilbane, 1997; Smith, 1995) and on the role of visual similarity in object recognition (Biederman, 1987; Ullman, 1989), this latter discussed also in relation to category-specific agnosias (see, for instance, Gale, Laws, Frank & Leeson, 2003; Gerlach, 2001; Laws, Gale & Leeson, 2003). Visual similarity also lies at the core of the debate on image-processing models for image matching and visual information retrieval (see, e.g., Super, 2002; Weken, Nachtegael & Kerre 2004; Zhao, Bhat, Nandhakumar & Chellappa, 2000). In all these studies the focus of attention has shifted from direct tasks asking participants to recognize the relationship being studied, to indirect tasks, from which the function of this relationship can be inferred. Independently of the development of the above mentioned new approaches to the study of similarity and diversity, the question to ask is if all the necessary work has been done to discover the perceptual structure (in gestaltic sense) of these relationships. In our view, analyses of visually perceived forms, in the style of Goldmeier's (1936/1972), can still contribute towards grounding cognition of Similarity, Diversity, Identity, etc. in perception (see, as an example of "grounding cognition" perspective: Coventry & Garrod, 2004; Pecher & Zwaan, 2005).

The hypothesis we are investigating in different perceptual domains (Bianchi, Savardi & Cattazzo, 2002; Bianchi, Savardi & Tacchella, 2002; Savardi & Bianchi, 2005, 2004a,b, 2001, 2000, 1997) is that people directly perceive oppositeness between objects, their parts, or their properties in the same way as they perceive sameness, similarity, or difference. If oppositeness has its own perceptual identity based on specific perceptual constraints, these could be described in terms of 'laws of perceptual oppositeness', just as other perceptual constraints were described as 'laws of perceptual similarity' (see Goldmeier, 1936; Palmer, 1978; but also Tversky, 1977; Medin, Goldston, & Gentner, 1990). In the framework of our approach, the study of oppositeness shifts from the domain of linguistics or lexical semantics (Croft & Cruse, 2004; Cruse & Pagona, 1995; Jones, 2002; Lehrer, 1985; Mettinger, 1994) to a phenomenological analysis of *what observers recognize* as opposite properties, opposite motions, opposite gestures, opposite objects, etc.

The experiments described in the present study used simple, two-dimensional geometric figures in order to reduce the number of variables under study and to give priority to visual structure over the semantic identity of objects. In Experiment 1, participants were asked to *produce* the opposite of a given figure. In Experiments 2 they were asked to *recognize* oppositeness in pairs of figures. The two tasks (production and recognition) involve two different processes. In fact, production tasks start from the observation of only one figure (e.g., "look at this figure and draw its opposite") and participants must *predict* which transformation will best generate the opposite of a given figure. Therefore, this type of task helps us to understand what properties of the initial figure are considered to be the best in terms of producing the required result. On the other hand, when asking participants to look at pairs of figures and indicate the ones perceived as opposite (recognition task), participants are asked to observe the relationship that is *visible between* two figures and determine whether what they perceive is oppositeness.

Experiment 1: Producing the opposite of a figure

The first hypothesis in this study concerned the number of transformations required to generate the opposite of a given figure. We considered whether systematic transformations would be applied to all or at least some of the properties of a figure, or whether only a few properties would be subject to transformation. This aspect was referred to as "*additivity vs. non-additivity*".

Secondly, we wanted to understand whether participants focused on certain characteristics more frequently than on others. This second aspect was referred to as *property requiredness*, using Koffka's (1935) original meaning to refer to the effect that one part (or quality) of a perceptual field may have on another or on the observer (e.g., a circle with a small segment missing demands to be completed; an incompletely folded piece of paper requires to be well-folded or unfolded).

We then studied whether passing from a given quality to its opposite in both directions (e.g., from small to large and from large to small) produces the same result in terms of oppositeness. The answer to this question (*isotropy/anisotropy of* *opposite directions of transformation)* is not as obvious as one might think and can only be resolved empirically. There is no reason to think that the transformation of a quality into its opposite and vice versa must necessarily be perceptually equivalent.

Two groups of participants across a wide range of ages (see method) were used to verify that participants' responses could be generalized despite different age groups.

Method

Sixteen figures obtained by transforming a square (Q) using the variables of Shape (H), Orientation (O), Surface (S), Size (Z), and their combinations were used as stimuli (Fig. 1). A square was chosen because of its extreme simplicity. The four variables studied (Shape, Orientation, Surface, and Size) can be considered the basic properties of a figure. They are the same Wertheimer used in 1923 to study the effect of similarity in visual organization.

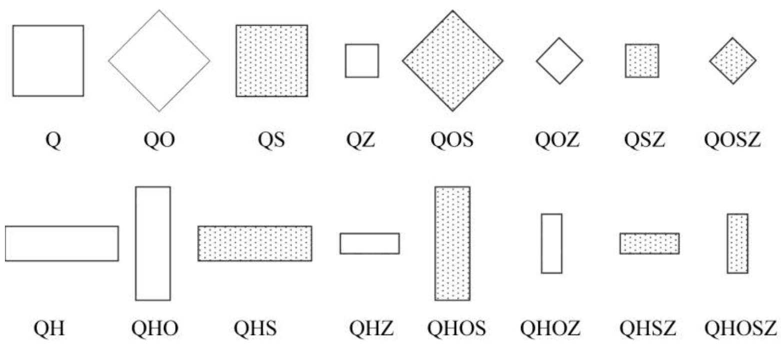


Figure 1. The 16 figures used in the experiment. The initials under each figure indicate transformation type (Shape = H; Orientation = O; Surface = S, Size = Z), as applied to a square (Q).

Two levels for each independent variable were considered.

Shape (H): equilateral vs. elongated. The presence/absence of a main elongation axis represents a quality that strongly characterizes the identity of visual objects (Boutsen & Marendaz, 2001; Howard, 1982; Kopferman, 1930; Marr, 1982; Metzger, 1971; Palmer, 1990; Quinlan & Humphries, 1933; Sekuler, 1996). This variation however ensures the stable maintenance of the other salient features of the figure (such as four-sidedness, symmetry, closure, and regularity).

Orientation (O): *coronal vs. gravitational*. Howard and Templeton's terms were adopted to indicate, respectively, the *horizontal* and *vertical* orientation. The coronal orientation characterized both the initial figure, the square (Q in Fig. 1), and the horizontal rectangle (QH in Fig. 1), which was derived from the square by means of the Shape transformation. Corresponding gravitational orientations were obtained by tilting the square 45° (QO in Fig. 1), which we then called square$_{45°}$, and by tilting the horizontal rectangle 90° (QHO in Fig. 1). As mentioned previously, the main elongation axis is a fundamental variable for perceiving the orientation of a figure. Hence, our stimuli were also characterized by *different degrees* of orientation (greater for *elongated* figures and lesser for *equilateral* ones).

Surface (S): *filled* (textured, with random dots) *vs. empty* (non-textured).

Size (Z): *small* vs. *large*. Size was determined by referring to the cardboard templates on which the figures were drawn (15 x 10.5 cm). Figures belonging to the same level (small or large) were perceptually equivalent in size. "*Small"* corresponded to 1 x 1 cm equilateral shapes and to 0.5 x 2 cm elongated shapes, "*large* " corresponded to 5 x 5 cm equilateral shapes and to 2 x 8 cm elongated shapes.

Participants. Fifty children, aged 5-7 years (the child group: Gc) and fifty university students, aged 20-30 years (the adult group: Ga), took part in the experiment.

Procedure. Participants were given 16 white cardboard templates, stacked in random order, each presenting one of the 16 figures on the left side. The task was to produce the opposite of this figure, drawing it on the right side of the template. Participants were free to choose which figures to start with and in which order to proceed. Figure names were never mentioned in order to avoid verbal descriptions in participant's visual recognition of stimuli.

Results and discussion

Results are presented in Table 1. Participants' responses were classified based on the criteria used to create the 16 original figures. Each response was therefore analyzed in terms of number and type of transformations applied. For example, if a participant drew the opposite of the large, coronal, textured rectangle (QHS in Fig. 1) as a large, gravitationally-oriented, empty rectangle (QHO in Fig. 1), the response was categorized as a two-property (Orientation and Surface) opposite.

Table 1. Production task response types (H = Shape, O=Orientation, S=Surface, Z=Size) and relative frequencies.

Transformations		Child Group (Gc)			Adult Group (Ga)		
Nr	Type	f	f% of General Totals	f% on Totals within number of transformations	f	f% of General Totals	f% on Totals within number of transformations
1T	**H**	14	1.75	2.33	87	10.46	24.79
	O	466	58.25	77.82	169	20.31	48.15
	S	60	7.50	10.01	77	9.25	21.93
	Z	59	7.37	9.84	18	2.16	5.13
	Totals 1T	*599*	*74.87*	*100*	*351*	*42.18*	*100*
2T	**HO**	6	0.75	3.14	25	3.00	7.18
	HS	6	0.75	3.14	104	12.50	29.89
	HZ	-	-	-	59	7.09	16.95
	OS	145	18.12	75.92	100	12.02	28.74
	OZ	17	2.12	8.90	16	1.92	4.60
	SZ	17	2.12	8.90	44	5.29	12.64
	Totals 2T	*191*	*23.86*	*100*	*348*	*41.82*	*100*
3T	**HOS**	8	1	100	17	2.04	18.28
	HOZ	-	-	-	14	1.68	15.05
	HSZ	-	-	-	38	4.57	40.86
	OSZ	-	-	-	24	2.88	25.81
	Totals 3T	*8*	*1*	*100*	*93*	*11.17*	*100*
4T	**HOSZ**	2	0.25	100	8	1.00	100.0
	General Totals	*800*				*800*	

Note. Percentages are calculated based on the general total for each group (Child Group and Adult Group) and within "number of transformation" categories (1T, 2T, 3T, 4T).

Non-additivity rule: Independently of transformation type, participants tended not to intervene on all or most properties of the given figure, but only on *one* or *two* qualities (see Fig. 2, and frequency of 1T or 2T in Tab. 1). Transformations of only one or two properties represented more than 80% of total responses in the adult group and more than 95% of total responses in the child group. The frequency of single transformations (1T) was higher in the child group (Gc = 74.87%, Ga = 42.18%; $z = 12.61$; $p < 0.001$).

Therefore, in terms of the number of transformations that participants used to produce opposite figures (the additivity vs. non-additivity rule), the results showed that participants followed a non-additivity rule.

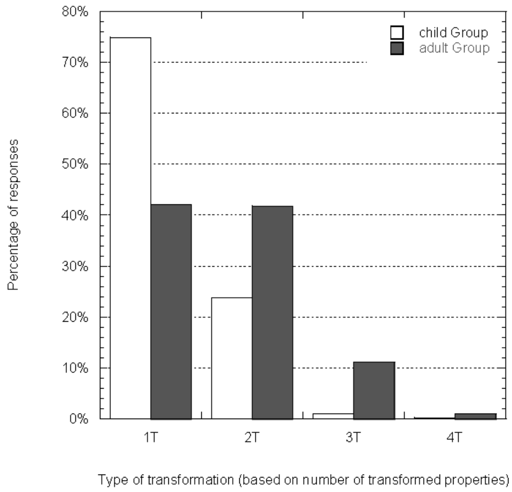


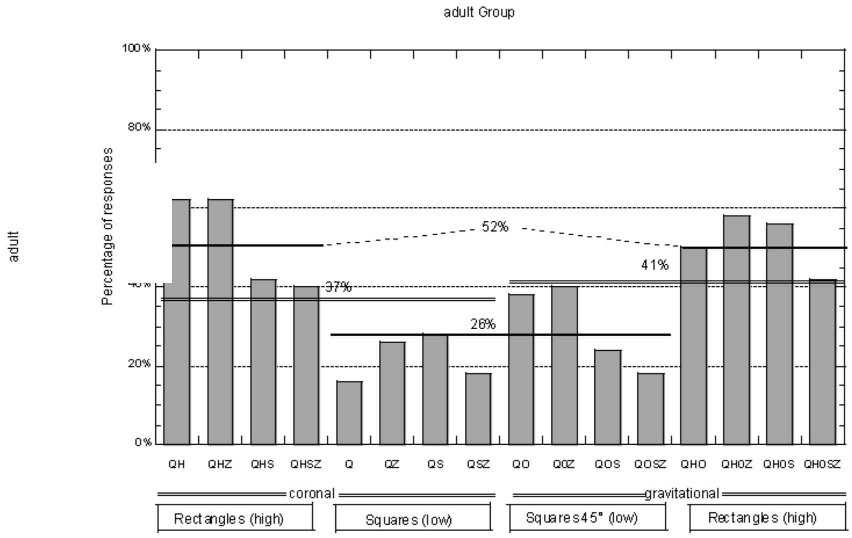
Figure 2. Frequencies of responses transforming one (1T), two (2T), three (3T) or four (4T) properties of the original figure in order to produce its opposite.

Property requiredness. Which properties did participants focused on more? In both groups, the most frequent transformation was that of figure Orientation (O). Preference for this type of single transformation (1T) was particularly evident in the child group, where it represented 58.25% of total responses (77.82% of 1T). Although the adult group showed a significantly lower frequency of this response type ($z=-11.30$; $p < 0.000$), with just 20.31% of total responses (48.15% of 1T), it was nonetheless the most-used transformation. The younger participant group's clear-cut preference for the property of Orientation was also confirmed for double transformations (2T): the second-most frequently used response (18.12%, that is 75.92% of 2T) was the Orientation/Surface transformation. In single transformations (1T), alongside Orientation, the adult group showed a rather frequent preference for either the Shape (H) or Surface (S) – respectively, 24,79% and 21.93% of 1T. In transformations of two properties, adult participants drew figures that were opposite in terms of either Shape and Surface (HS = 29.89% of 2T), Orientation and Surface (OS = 28.74% of 2T).

These are the results that emerged from a general analysis of the four variables. In the following pages, a more thorough analysis of the data is conducted which examines the responses according to variable levels, looking at the results for each individual property.

I) Orientation transformation: more frequent with figures showing a high degree of orientation. It is important to remember that--independently of Surface and Size levels--8 of the 16 figures (Fig. 1) presented a coronal orientation axis, and the remaining 8 figures had a gravitational orientation axis (see also description below x axis, in Fig. 3). For each of these groups, 8 figures have a high degree of orientation (i.e., figures with an elongated shape: see “rectangles” in Fig. 3) and 8 figures have a less accentuated degree of orientation (i.e., figures with an equilateral shape: see “squares” and “squares$_{45°}$“ in Fig. 3). The following analyses were conducted by comparing the two degrees of orientation (high vs. low) and the two axes of orientation (gravitational vs. coronal). For the 8 figures satisfying each level of Orientation examined, a sample of 400 responses (50 participants x 8 figures) was considered.

As shown by the percentages of responses in Fig. 3, participants applied the Orientation transformation more frequently to figures with a *high degree of orientation* (Rectangles) than to figures with *less accentuated orientation* (Squares and Squares$_{45°}$) This difference was found in both the adult (52% *vs.* 26%; z= 8.92, $p < 0.001$) and child groups (86% *vs.* 73%; z = 4.55, $p < 0.001$). Conversely, non-significant differences were found between figures oriented *coronally* or *gravitationally*. Once more, this result was observed in both the adult (37% *vs.* 41%; z= -1.37, n.s.) and child groups (77% *vs.* 82%; z=1.75, n.s.).



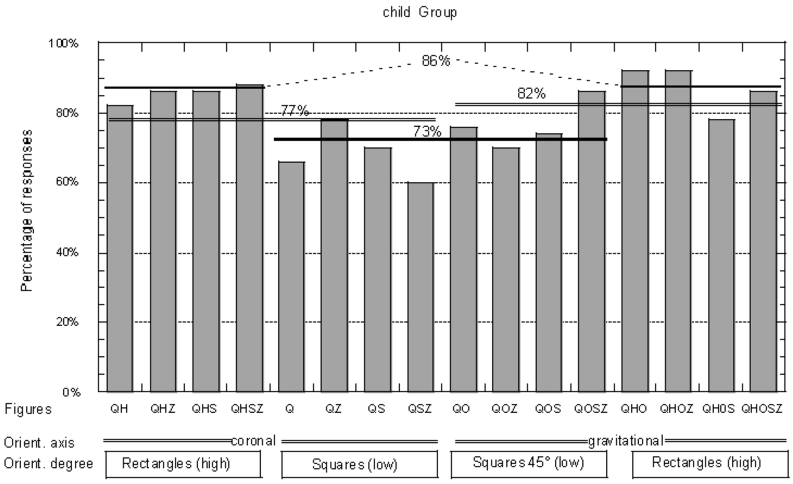


Figure 3. Percentage of Orientation axis transformation (simple or combined), according to figure type, for the adult and child groups, respectively.

Note. The x axis is organized into separate categories, based on the Orientation axis (coronal vs. gravitational) and the degree of orientation, which depends on Shape variable levels (a high degree for elongated and a low degree for equilateral shapes). Percentages were calculated on response totals for each figure (n=50).

II) Shape transformation: more frequent in adults and in the equilateral to elongated direction. The Shape transformation was highly infrequent in the child group (<5% of total responses, considering both single and varyingly-additive solutions). This result therefore suggests the low requiredness of this variable in younger participants.

Table 2. Shape transformation types and relative frequencies in the Adult group.

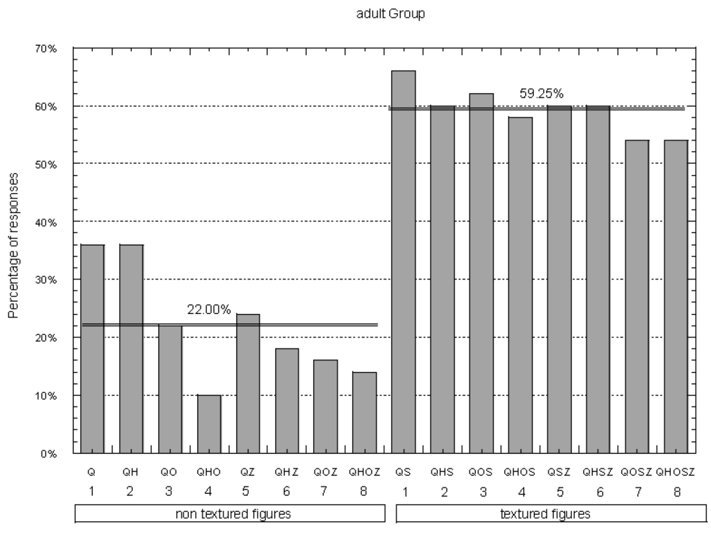
Number of transformations	Shape (H) transformation type	f	f%
1T	$H_{angular\text{-}round}$	109	30.97
	$H_{equilateral\text{-}elongated}$	200	56.82
2T	$H_{angular\text{-}round}$+ $H_{equilateral\text{-}elongated}$	34	9.66
	$H_{angular\text{-}round}$+ Orientation	9	2.56
tot		352	100.00

Adults used the Shape variation, whether single or combined (1T + 2T), in 44.0% of responses. As shown in Tab. 2, in 56.8% of these cases, the transformation was equilateral-to-elongated and in 30.9% angular-to-round transformation. Transformations associating the variations angular-to-round and equilateral-to-elongated (9.66%) or the angular-to-round and Orientation transformations (2.56%) were rather infrequent. Both the equilateral-to-elongated transformation and the angular-to-round transformation were applied more frequently to figures with a low degree of orientation (squares or squares$_{45°}$) than to figures with a high degree of orientation (coronal or gravitational rectangles) – equilateral-to- elongated: $z=3.90$, $p < 0.001$: angular-to-round: $z=3.90$, $p < 0.001$.

To summarize, *rectangles* seemed to call for the Orientation transformation more frequently than the Shape transformation (O: 51.5% of total responses; H: 33.75%; $z=2.51$, $p < .05$), independently of whether the latter was the elongated-to-equilateral or the angular-to-round transformation. Conversely, for *equilateral figures*, the Orientation transformation was less frequent than the Shape transformations (O: 26.0%; H: 58.5%; $z = -4.65$, $p < .001$).

III) Surface transformation: infrequently used. As shown in Tab. 1, this transformation was very infrequent as a single variation (1T) in both the child group and adult group (respectively, 7.50% and 9.25% of response totals). It was used more frequently in combination with other transformations (>1T) both by children (1T: 7.5% vs. >1T: 22.7%; $z = -11.41$, $p < 0.001$) and adults (1T: 9.2% *vs.* >1T: 41.8%; $z = -14.74$, $p < 0.001$).

A comparison of the percentages of responses modifying surface for *textured* figures (8 of the 16 figures used: see Fig. 1) and *non-textured* figures (the remaining 8 figures in Fig. 1) showed that this transformation was most used in one direction. Namely, when the initial figure was *filled* and the change consisted of emptying the figure. This result was found both in the child group (12.75%$_{[empty-filled]}$ *vs.* 44.25%$_{[filled-empty]}$: $z = -9.87$, $p < 0.001$) and adult group (22.00%$_{[empty-filled]}$ *vs.* 59.25%$_{[filled-empty]}$: $z = -10.73$, $p < 0.001$) and was confirmed *for all figures* (see Fig. 4).



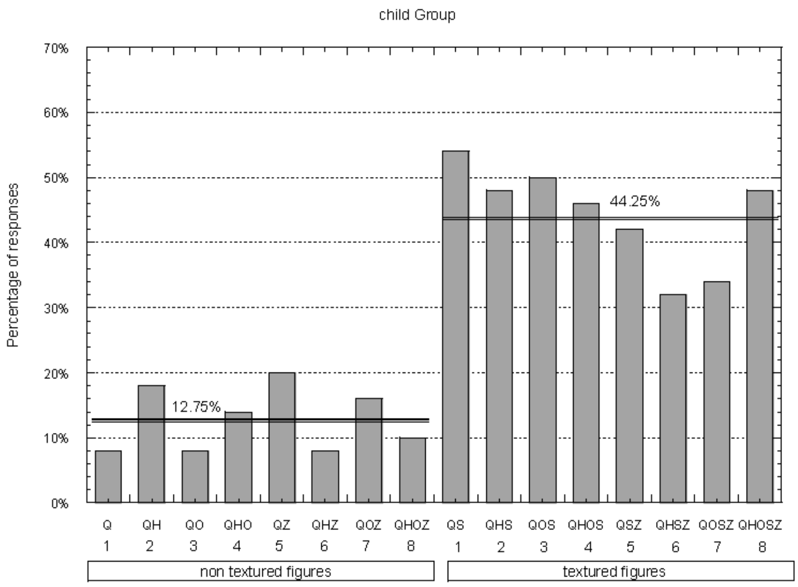


Figure 4. Percentages of Surface transformation (simple or combined) for the 8 textured and the 8 non-textured figures, in the adult and child groups, respectively.

Note. The numbers appearing under the initials, for each bar, indicate corresponding textured/non-textured figures. Percentages were calculated on the total number of responses for each figure (n=50).

IV) Size transformation: infrequently used. In terms of overall totals (Tab. 1) single transformations (1T) of this property were infrequent in both groups (Ga: 2.16%; Gc: 7.37%), although children used it more frequently ($z=-3.21$; $p < 0.01$) than adults. Adults used it in combination with another transformation more frequently than on its own ($z=13.38$, $p < 0.001$). Conversely, children used the Size transformation more frequently on its own than in combination with other variables ($z=2.68$, $p < 0.01$) .

A comparison of overall response percentages for the 8 small figures and the 8 large ones (n = 8 figures x 50 participants, for each level) yielded no significant differences between enlarging small figures or reducing large figures, in either the adult ($18.5\%_{[small-large]}$ *vs.* $15.75\%_{[large-small]}$; $z=1.03$, n.s.) or the child group ($10.25\%_{[small-large]}$ *vs.* $13.00\%_{[large-small]}$; $z=-1.21$, n.s.).

A Multiple Correspondence Analysis conducted on the general data showed different results for Size transformation in equilateral and elongated figures (second factor extracted: 24.2% of total variance), suggesting that further visual transformations may be introduced by a size change. Namely:

a) Size transformation was more frequently applied to equilateral figures than to rectangles. A possible interpretation of this result is that size transformation resulted in a general size enlargement or reduction when applied to equilateral figures, while it either increased (from small to large) or decreased (from large to small) the degree of figure orientation, rather than showing general enlargement or reduction, when applied to rectangles.

b) A difference was noticed between the use of Size transformation when applied to squares$_{45°}$ and gravitational rectangles as opposed to squares or the coronal rectangles. This result suggests that size variation may create a different effect in the two groups of figures: in the former group, enlargement increased the figure instability, whereas size reduction lessened it. In the latter, enlargement increased the figure stability, whereas size reduction mantained it .

Experiment 2: Recognizing the opposite of a figure

Experiment 2 looked at the question of whether pairs of quantitatively-equally opposite figures (i.e., all showing two figures that are identical except for *one* opposite property) show *the same degree* of oppositeness *qualitatively*. This aspect was referred to as *property suitability hypothesis.*

The four transformations used in experiment 1 (Shape, Orientation, Surface, and Size) were studied in a recognition task. By presenting both possible directions of transformation (i.e. the pair large-vs.-small-square and the pair small-vs.-large-square), the hypothesis of *transformation isotropy/anisotropy between two opposite poles* was investigated.

Method

The same 4 variables studied in Experiment 1 were used:

- Shape (H): equilateral vs. elongated;
- Size (Z). small vs. large;
- Surface (S): filled (textured) vs. empty (non-textured);
- Orientation (O): coronal vs. gravitational axes.

Participants. The study was conducted on a group of fifty children, aged 5-7 years (the child group: Gc) and a group a seventy undergraduate university students, aged 19-30 years (the adult group: Ga).

Procedure. Participants were presented with a set of 4 pairs of figures (line-drawings). There were 16 sets in total. Each pair of figures was printed on a 20 x 14 cm cardboard template. Each set consisted of 4 pairs of figures (Figure 5 shows an example of one of the 16 sets used). One of the figures remained constant for each set and always appeared on the left side of the template (the ‘standard figure’ of the set). The other figure, printed on the right side, was opposite in terms of one of 4 examined properties (H, Z, S, O). Each set of 4 templates was given to participants with the templates in random order. Participants were asked to line up the 4 pairs vertically, so that the ‘standard figure’ (identical for all 4 pairs) always appeared on the left. Then, they were asked to rank the 4 pairs from the most- to the least opposite.

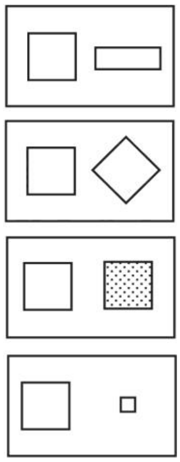


Figure 5. One of the 16 figure sets used in the experiment. The 'standard figure' is on the left of each pair and remains constant for each set. The figures shown on the right are opposites in terms of, respectively, Shape (equilateral-elongated), Orientation (coronal-gravitational), Surface (empty-filled) and Size (large-small).

Results and discussion

An overall analysis of responses to the 16 sets showed high variability in the ranking of the four transformations (see Tab. 3). However, a high degree of agreement between participants (verified by Kendall's W test) was found for the ranking of the 4 pairs within each set, for 15 out of 16 sets in the adult group and for 10 out of 16 sets in the child group (Tab. 4). These two results once more emphasize the specificity of the outcome for the same transformations (H, O, S, and Z), depending on the pairs of figures used. The question "Which of the 4 variables of Shape, Orientation, Surface, and Size are the most suitable to generate oppositeness?" can thus be better answered by looking at specific pairs of figures. Some general observations can however be made by noting the frequency of responses in the top two rankings (I or II) and those in the two lower ranking positions (III or IV):

Table 3. Distribution of Shape (H), Orientation (O), Surface (S), and Size (Z) transformations, independently of specific pairs, in rankings I-IV (in decreasing degree of oppositeness).

		Rankings					Combined rankings		Difference between combined rankings	
Group	Transformation	I	II	III	IV	tot	I+II	III+IV	χ2	p
Gc	H	41.37	13.88	14.25	30.50	100.00	55.25	44.75	8.820	0.003
	O	24.37	29.50	35.63	10.50	100.00	53.88	46.12	4.805	0.02
	S	13.50	24.00	24.88	37.62	100.00	37.50	62.50	50.000	0.000
	Z	20.75	32.63	25.25	21.38	100.00	53.38	46.63	3.645	0.05
Ga	H	46.60	17.14	15.63	20.63	100.00	63.75	36.25	84.700	0.000
	O	21.34	29.55	24.11	25.00	100.00	50.89	49.11	0.355	n.s.
	S	20.45	17.32	30.72	31.52	100.00	37.77	62.23	67.009	0.000
	Z	11.61	35.98	29.55	22.86	100.00	47.59	52.41	2.602	n.s.

Note. Percentages calculated on total number of responses for overall sets (n=800 for the Child group: 50 subjects x 16 sets; n= 1.120 for the Adult group: 70 subjects x 16 sets).

A) Both the child and adult groups ranked the Shape transformation in the top two positions more frequently than in the lower rankings (see Tab. 3, Difference between combined rankings for H). A between groups comparison revealed that adults did this more frequently than children ($z=3.00$, $p < .01$). This result is consistent with the more frequent use of the Shape transformation in the adult group, found in Experiment 1.

B) Both groups ranked the Surface transformation more frequently in the lower positions (See Tab. 3, Difference between combined rankings for S), with very similar frequency ($z= 1.47$, n.s.).

C) The adult group did not significantly differ in its ranking of the Size transformation and Orientation transformation in the top two or the lower two positions, whereas the child group ranked it more frequently in the top two positions (See Tab. 3, Difference between combined rankings for Z and O).

Therefore, the variation in the suitability of the 4 transformations in terms of making two figures visually opposite can be inferred at a superficial level from these data. By shifting the focus of the analysis internally to the 4 variables, one can get a better understanding of the degree of oppositeness attributed by participants to the specific figure pairs.

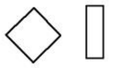
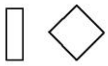
Table 4. Agreement (Kendall's W coefficient of concordance) on rankings of the 4 pairs of figures, for each of the 16 sets (the set is indicated by initials of the 'control figure').

Figure Set	child Group			adult Group		
	W	χ^2	p	W	χ^2	p
Q	0.086	12.84	0.005	0.130	27.30	0.000
QH	0.052	7.80	0.050	0.092	19.42	0.002
QO	0.087	12.98	0.005	0.094	19.76	0.000
QS	0.092	13.72	0.003	0.078	16.40	0.000
QZ	0.117	17.496	0.001	0.113	23.81	0.000
QHO	0.116	17.352	0.001	0.132	27.77	0.000
QHS	0.002	0.312	n.s.	0.139	29.19	0.000
QHZ	0.024	3.672	n.s.	0.054	11.53	0.009
QSZ	0.034	5.112	n.s.	0.018	3.92	n.s.
QOZ	0.040	6.048	n.s.	0.089	18.87	0.000
QOS	0.084	12.576	0.006	0.150	31.62	0.000
QOSZ	0.052	7.848	0.049	0.095	20.04	0.000
QHOZ	0.229	34.296	0.000	0.042	8.81	0.031
QHOS	0.022	3.264	n.s.	0.079	16.61	0.000
QHSZ	0.048	7.200	n.s.	0.047	9.89	0.019
QHOSZ	0.117	17.496	0.001	0.083	17.43	0.000

Note. *df* = 3

Shape oppositeness: equilateral vs. elongated. Table 5 illustrates the four types of figure pairs showing the Shape transformation in the directions of elongated-to-equilateral (*a, d*) and equilateral-to-elongated (*b, c*), independently of Size and Surface levels. As the percentages show, pair *b* was least frequently chosen as the most opposite (rank I) than the other pairs. In particular, it was less frequently attributed to rank I also than pair *c* ([Gc]: $z = - 2.23$, $p < .05$; [Ga]: $z = - 5.21$, $p < 0.001$) ---which nevertheless showed the equilateral-to-elongated variation. This suggests that, more than transformation direction (from equilateral to elongated), it is the specific visual characteristics of pair *b* that render this pair so "un-opposite".

Table 5. Percentage of responses assigning Shape transformation to rank I, in function of pair type, for the two groups.

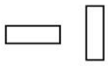
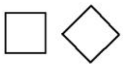
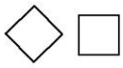
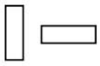
Pair Type		child Group	adult Group
a		48%	58 %
b		37%	37 %
c		48%	59 %
d		54%	54 %

Note. Percentages refer to overall frequencies for the four presented variations of the same transformation type (independently of the 2 levels of Size and Surface). The figure pairs in the table show only one example per pair type.

A comparison of rankings attributed to inverse pairs confirmed that perceived oppositeness in figure pairs, the first figure of which is equilateral and the second elongated, is no greater than the oppositeness observed for pairs showing the inverse oppositeness transformation. In fact, a sign test revealed that at least 50% of participants attributed the same rank to inverse pairs in 6 out of the 8 comparisons studied. Thus, we may ask which characteristic makes pair b less opposite than the other three pairs (Tab. 5). We suggest that shape variation in this pair better preserves the original identity. This is certainly true compared to pairs c and d where the equilateral figure (square $_{45°}$) has a perceptual angularity different from that of the rectangles with which it was paired. This is also true, however, when comparing it to its inverse pair (pair a). In fact, whereas the pair b transformation is presumably identified as a decrease in height or a loss of equilaterality, rather than an increase in length, the transformation that is visible in pair a shows an increase in height and equilaterality, and not a reduction in width. Hence, the pair b transformation is much more conservative as it represents rather the loss of a property than pair a, where the new figure takes on different qualities.

Orientation oppositeness: coronal vs. gravitational. As in Table 5, Table 6 shows a comparison of the 4 types of Orientation transformation used in the study (independently of Surface and Size variations).

Table 6. Percentage of responses assigning Orientation transformation to rank I, according to pair type, divided by group.

Pair Type		child Group	adult Group
a		24%	24 %
b		34.5%	34 %
c		12%	6 %
d		27%	18 %

Note. The figure illustrates the pair type at only one level per variable.

The direction of the transformation appeared to influence the perceived degree of oppositeness: rank I attributions were more frequent for pairs showing the coronal-to-gravitational oppositeness transformation (mean for *a* and *b* pairs) than for the inverse direction (mean for *c* and *d* pairs) in both the child group (M[a,b]=29%, M[c,d]=19.5%: z=3.13, $p < 0.01$) and the adult group (M[a,b]=29%, M[c,d]=12%; z=7.05, $p < 0.001$). However, in both groups the difference between coronal-to-gravitaional and vice versa was attributable only to pairs *b* and *c*, which were made up of equilateral figures (Gc: z=-5.23, $p < 0.001$: Ga: z=-8.28, $p < 0.001$). No significant differences emerged between pairs *a* and d, which were made up of elongated figures (Ga: z=1.74, n.s.; Gc: z=-0.69, n.s.). The difference between pairs *b* and *c* was confirmed by Wilcoxon tests conducted on all four *b*- and *c*-type pairs, with the various Surface and Size levels. The tests were significant for 3 out of 4 pairs in the child group and for all 4 pairs in the adult group (Tab. 7).

Table 7. Comparison of ranks (Wilcoxon test) attributed to corresponding pairs showing two inverse Orientation transformation levels: gravitational-to-coronal vs. coronal-to gravitational.

Inverse Pairs	child Group z	child Group p	adult Group z	adult Group p
(QO,Q) *vs.* (Q,QO)	-2.207	0.05	-2.601	0.01
(QOZ,QZ) *vs.* (QZ,QOZ)	3.295	0.001	-4.523	0.000
(QOSZ, QSZ) *vs.* (QSZ,QOSZ)	-1.974	0.05	-2.868	0.004
(QOS,QS) *vs.* (QS,QOS)	-1.470	n.s.	-3.408	0.001

Note. The pairs analyzed comprised equilaterally-Shaped figures (pairs *b* and *c* in Tab. 6).

Thus, it is not possible to conclude that transformations from the coronal to the gravitational axis produce more evident oppositeness than transformations in the inverse direction, independently of the characteristics of a figure. In pairs b and c, the Orientation transformation also strongly modified the qualitative aspect of the figure (see Mach's comments concerning these figures, made as early as 1896). We suggest that it is the stability-instability dimension that most influences the perception of the degree of oppositeness in these two inverse pairs. In fact, the square$_{45°}$ presents qualities of instability, angularity, and dynamism, which the square (appearing perceptually stable) does not. Hence, the stability-instability variation seems to generate the perception of more oppositeness than the inverse variation.

Surface Oppositeness: *filled vs. empty*. In both groups, the filled-to-empty transformation was not considered to render two figures visually opposite. In fact, as discussed previously in our general data presentation (Tab. 3), participants assigned this variation more frequently to the last two rankings.Unlike the findings from Experiment 1, pairs showing the empty-to-filled transformation (adding texture or filling-in) did not differ in degree of oppositeness from the filled-to-empty pairs (texture removal or emptying out). The difference between percentages (combined ranks I or II) was not significant in either the child group (empty-filled = 39.75%, filled-empty = 37.50%; z=0.65, n.s.) or the adult group (empty-filled = 26.07%, filled-empty = 24.46%, z = 0.62, n.s.).

Size oppositeness: small vs. large. Only 11.8% of total adult participant responses indicated this transformation as the most opposite of the 4 proposed alternatives (rank I), whereas a significantly higher percentage of children (20.75%; z = 5.41, $p < 0.001$) rated it as most opposite (see Tab 3). This result was in agreement with the children's more frequent use of this variation in Experiment 1.

The degree of oppositeness generated by the Size variation changed according to the direction (see Fig. 6). More specifically, attribution to top ranks (I or II) occurred more frequently for pairs showing small-to-large transformations (enlargement) as compared to pairs showing a reduction in size. This result was observed in both the child (small-large = 60.5%, large-small = 46.5%; $z = 3.97$, $p < 0.001$) and adult groups (small-large = 62.5%, large-small = 31.61%; $z = 10.36$, $p < 0.001$). A comparison of corresponding pairs (by Wilcoxon test) yielded a significant difference in adult group rankings in favor of enlargement for 7 out of 8 inverse pairs, and in child group rankings for 4 out of 8 inverse pairs.

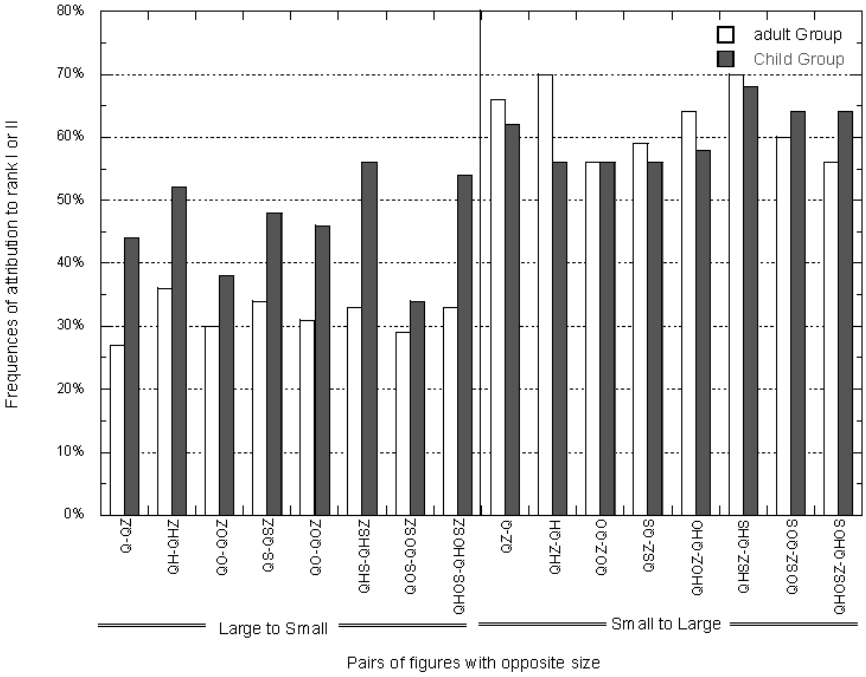


Figure 6. Frequency of top rankings (I and II) for Size transformations in both groups are presented according to pair figures. Initials under the x axis indicate corresponding inverse pairs; asterisks on top of the bars indicate the significance of frequency difference between inverse pairs (Wilcoxon test).

Note. Percentages are calculated on the following samples: Child Group (Gc): n=50, Adult Group (Ga): n=70.

In both groups greater oppositeness (assignment to rank I) was recognized when enlargement was applied to equilateral figures, than to elongated figures (Gc: [I]equilateral =34.5%, [I]elongated =23.5%, $z=2.42$, $p < 0.05$; Ga: [I]equilateral=23.2%, [I]elongated =12.1%, $z=3.44$, $p < 0.01$). This finding is similar to the results in Experiment 1 (see Multiple Correspondence Analysis). This result was not fodu for the inverse direction of large-to-small (Gc:

[I]equilateral=13%, [I]elongated=12%, z=0.30, n.s.; Ga: [I]equilateral=5.7%, [I]elongated=3.9%, z=1.00, n.s.). Thus, changing from large to small, the shape of the object does not seem to affect the degree of oppositeness perceived within the pairs of figures.

General discussion

The results of Experiment 1 enabled us to establish that when participants are instructed to produce the opposite of a simple geometric figure, they tend to alter one or, at most, two properties of the initial figure. This result confirms what we had already found in recognition tasks (see Savardi & Bianchi, 2000, 2004a,b): when presented with pairs of figures with variations involving more than one or two features, participants tended to classify them as "different figures" rather than "opposite", and to give them very low rankings on a scale of oppositeness. Taken as a whole, these findings show that one of the 'rules' of visual oppositeness is what we suggest calling the "Principle of invariance" (Savardi & Bianchi 2000, Savardi & Bianchi 2005): a necessary condition for two events under observation to be perceived as opposites is evident similarity.

It is interesting to note that that the question of the number of properties transformed has emerged numerous times over a very long period in the feature-based analysis of similarity and difference, which came before the current analysis of oppositeness (Aristotle, *Metafisica*, V (Δ), 9, 1919a 15; Goldmeier, 1936; Hume, 1793; Meinong, 1882; Tversky, 1977; Palmer, 1978). These earlier analyses mainly considered whether the perceived similarity or difference between two objects depends on the number of features they have in common. From the very first experiment conducted on similarity (Goldmeier, 1936), this variable proved to be crucial while at the same time inadequate. A similar conclusion is at the heart of Tversky's (1977) "contrast model", which the author presented as a qualitative psychological model (in contrast to metrical models) used to explain how similarity and difference function in everyday cognitive, perceptual and linguistic applications. The role of quantitative as well as qualitative aspects is clearly evident in Tversky's model and this was still retained in later formulations (Gati & Tversky, 1982, 1984; 1987; Markman & Gentner, 1993; Sattath & Tversky, 1987). Without going into details of these models and of their differences, what we would like to emphasize is that in all of these cases similarity and difference/diversity have, as critical factors, the number and (perceptual) salience of common and distinctive features. As our data suggest, the variable of number is also important for the perceptual definition of oppositeness. Moreover, the latter relationship seems to be closer to similarity than to diversity in that it shares with similarity the condition of transforming only a few properties, given the maintenance of the overall identity of the opposite/similar object or events (see Bianchi, Bressanelli, Nucci & Savardi, 2003; Savardi & Bianchi, 2000).

Beside the *quantitative* aspect mentioned above, results from experiment 1 also showed *qualitative* preferences in participants responses: in fact, they tended to transform the Orientation axis for figures with a salient orientation, whether coronal or gravitational. Moreover, children tended to use this transformation with equilateral figures - at times, in association with Surface “emptying”. Conversely, with equilateral figures, adults tended to use either the transformation of figure equilaterality (by producing an elongated figure) or of angularity (by rounding the figure’s outline).

Independently of how frequently the given transformation was used, various anisotropies between the two possible direction of transformation emerged. In fact, participants transformed filled surfaces into empty ones, small figures into large ones, and equilateral figures into elongated ones more frequently than vice versa. Interestingly, these anisotropies were consistent over age.

The qualitative preferences for certain transformations and anisotropic effects of inverse transformations were further investigated in Experiment 2, in a recognition-of-figures context.

It is important to note that, based on the perceptual approach to the study of oppositeness that we propose, oppositeness contributes to the organization of the perceptual world in two different ways (Savardi & Bianchi, 2000; 2005): two events can be opposite in a way that is obvious to immediate observation, just as two events can be obviously identical, similar, or different. Yet, they can also be opposite to an analytical observation of their constituting properties. In fact, the figure pairs used in Experiment 2 recognition tasks all consisted, analytically, in oppositeness transformations of one spatial property of the original figure. As the results from this experiment revealed, a highly variable global result corresponded to this analytical presence of oppositeness, being the figure pairs recognized as being more or less opposite in a “self-evident” sense.

Namely, Orientation transformation and shape transformation was suitable to generate obvious oppositeness with figures with a salient orientation axis and the and with equilateral figures, respectively, as long as the paired figures did not look too invariant. On the contrary, a small degree of oppositeness was recognized between figures that were opposite in terms of Surface or Size.

The discovery of directional anisotropies (or asymmetries) in our present and previous experiments extends precedent findings of anisotropies in similarity and diversity judgments to the case of oppositeness judgments. Tversky (1977) had originally observed that people’s similarity ratings of geometrical forms did differ depending on the direction of the comparison, when the compared figures varied in terms of goodness of form or complexity. Similarly, Rosch (1975) found directional asymmetries using varyingly-oriented straight lines and varyingly-hued color patches. Tversky’s initial findings were later widely confirmed in other studies using more complex configurations and cognitive concepts (Medin, Goldstone, & Gentner, 1993; Ortony, 1979; Ortony, Vondruska, Foss, & Jones, 1985). With respect to perception, anisotropies have been demonstrated to be relevant also in visual search tasks, leading researchers to conclude that features can be easier to detect in one, but not in the inverse direction (see, e.g., Kristjánsson, & Tse, 2001; Polk, Behensky, Gonzalez, Smith, 2000;-Treisman & Gormican, 1988; Treisman &

Souther, 1985; Wolfe, 2001). What we believe is worth being further investigated is how anisotropies affect the naïve recognition of oppositeness, when simple perceptual stimuli or more complicated cognitive or perceptual tasks/behaviors are involved.

Obviously, when searching for perceptual constraints, one must exercise caution and interpret one's results strictly in terms of the configurations that produce those results. The variation of one property of a configuration frequently involves other visible aspects of the configuration. In fact, we found that the same transformation from small to large perceptually accentuated either the degree of orientation of a figure (or simply increased its size) or increased the figure's instability in function of the object's structure. Similarly, the Shape transformation was found to change the identity of a figure, with various degrees of invariance. This result shows how the perceptual investigation of oppositeness must keep its hypotheses formulations and conclusion generalizations highly constrained, not only by specific variable levels, but also by the specificity of figures with given property levels. Nevertheless, this is also true for the entire filed of perceptual research.

However, previous research conducted in different domains (Savardi, & Bianchi, 2000, 2003, 2005) and the findings from the experiments described herein confirm the presence of some regularities in participants' responses, not only within each field, but also among different fields. The search for "laws", in a phenomenological sense, of perceptual oppositeness allows to extend current research on opposites from the filed of lexical semantics (…..) and of cognitive linguistics (…….), to the perceptual field. In other words, this means to open a new perspective on the investigation of "antonyms", grounding it on perception and action.

Zusammenfassung

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Summary

Two experiments investigated the oppositeness between simple geometric figures, with children and adult participants. Various transformations of a figure were studied, obtained by transforming one or more qualities into their opposite properties. In Experiment 1 participants were asked to produce an opposite figure and in Experiments 2 to recognize the most opposite of a figure in figure pair presentation.

Results showed that axis transformations generated obvious oppositeness in figures with a salient axis orientation. In Experiment 1, children also tended to favor Size and Surface transformation, while adults favored Shape transformation (equilateral-to-elongated and angular-to-round). These transformations, however, turned out to be less popular in the recognition task (Experiment 2). A general non-additive effect of combined transformations on the perception of oppositeness was found. Various anisotropies in the direction (e.g.: from small to large and viceversa) were identified in both production and recognition tasks.

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