4

Investigating contraries by means of change detection

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4.1 The overwhelming wealth of the environment

Since the richness and complexity of the environmental stimuli we are exposed to exceed the capacity of our visual system for analysis, we need to select those elements which contain most information and help us to obtain the best results (in terms of knowledge) with the minimum effort (in terms of cognitive processing). This selection process takes place along a spectrum that goes from a cursory perceptual representation to the encoding in memory of the information perceived (Van Rullen & Koch, 2003). This is why we think it would be better to conceive visual cognition in terms of graded access to environmental information: the facility of access to information is directly related to its level of priority, and priority, in turn, is given to a stimulus on the basis of either bottom-up or top-down factors.

As a result of the combination of these factors, the most informative elements are accessed immediately and the less informative are barely or not at all accessible. This selection allows our perceptual system to throw out the bathwater (i.e. what is uninformative) and save the baby (whatever has high information content). The challenge faced by our perceptual system is to understand what is important and

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where to find it (i.e. where the baby is) at the same time as getting rid of all the useless data that might overload it.

When we look at a scene, we do not systematically scan all its elements. In fact, there are some parts that are ignored and others on which the gaze rests. Furthermore, only some elements contribute to the creation of a coherent and stable representation, just as only some pieces of information are later recalled with precision. One of the first studies on this question was conducted by Buswell (1935), who noted that scanpaths tended to be significantly stable and recurrent in certain parts of the scene, in particular where people were depicted, while background areas were ignored. This was one of the first proofs that information is not distributed evenly across a scene but that there are some elements which are bearers of greater information. Similar results, as we shall see, were found by Antes (1974), Mackworth and Morandi (1967), and Rensink et al. (1997).

Therefore, when observer and environment meet, the result is not an exact copy that faithfully reproduces the details of the scene. This is especially true when continuous exploration, constant change of perspective and a dynamic environment is involved (change detection experiments provide an example of this). What we have, in contrast, is a rough representation, what we can call a *sketch*, constructed pre-attentively in a few hundred milliseconds (Biederman, 1981; Li, VanRullen, Koch, & Perona, 2002; Thorpe, Gegenfurtner, Fabre-Thorpe & Bülthoff, 2001; Torralba & Oliva, 2002; VanRullen & Thorpe, 2001) on the basis of those elements which have high "informativeness". By this we mean those features of a scene which bear more information and to which, therefore, priority is given in the processing carried out by our cognitive system. In other words, it is informativeness which guarantees whether a stimulus passes from the "primary, pre-category process of the formation of visual objects" to the "secondary process of identification and coding of the objects themselves" (Kanizsa, 1991). It is informativeness, that defines the quality of a representation and, in the last analysis, its conscious accessibility (Cleeremans & Jiménez, 2002).

We prefer to use the term Information Potential (IP), and not simply information, because we want to put the emphasis on the relative nature of the priority accorded to an element in a scene, which depends on factors such as the context into which it is placed and, especially, on the observer (Bracco & Chiorri, 2008).

In defining the various aspects of IP, we refer to low- and high-level factors. When observers look at a scene, various types of priority play a role: there are some areas of the scene that are more salient and others that are less salient based on their physical characteristics (luminance, contrast, size, position, orientation, color, movement, etc.); other elements may be privileged based on their surrounding context, how much information they convey, the instructions given and the various different motivations, needs, preferences and experiences of the observers (Chun & Marois, 2002; Henderson, Weeks & Hollingworth, 1999; VanRullen, 2003). The priorities according to which we process the elements of a scene can be placed along a notional *continuum* and can range from features that are clearly linked to the object (*bottom-up*) to typically subjective proprieties (*top-down*) (Figure 4.1).

For brevity's sake, let us focus on those aspects that are grouped under the bottom-up category and that are outlined in the left part of Figure 4.1. For a deeper explanation of all of these properties see Bracco & Chiorri (2008). Our visual system is "calibrated" (we might also say "wired") to be sensitive to certain purely physical characteristics of a percept: inevitably we train our gaze on areas of high luminance or high contrast, in the same way as our attention is caught by stimuli that are either in movement or by configurations (orientation, texture, size, etc.) which *pop out* from the rest (Treisman, 1985, Treisman & Gelade, 1980; for a review, see Wolfe, 1998). Such characteristics are inherent in the stimulus but do not represent an absolute priority, tending rather to confer priority only on other elements that have different and lower values than that feature (for example, a red stimulus is not, by itself, salient, but becomes so if surrounding by stimuli coming from another color make it stand out).

Objective, hard-wired, bottom-up ⟷ **Subjective, contingent, top-down**

Aspects of the INFORMATION POTENTIAL

Pop out of salient elements	**Gestalt Properties**	**Proto-object formation**	**Typicality or diagnosticity**	**Incongruence of the element in the scene**	**Fundamental motivations**	**Contingent motivations**	**Personal experience**
Brightness, Contrast, Movement, Color, Dimension, Etc.	*Prägnanz* Goodness, Similarity, Figure/ground, Etc.	Pre-attentive perceptual structure with a limited spatio-temporal coherence	Frequency, uniqueness and distinctiveness of the element	Novelty, originality, oddness, incongruence of the element with respect to to the scene context	Needs, emotional states, events with high personal relevance independent from the current situation (one's own name, faces, etc.)	Experimental instructions, expectations, Priorities bound to the current task, etc.	Subject's past experience and specific competencies (*expertise*)

Figure 4.1 The main aspects of Information Potential.

As other models show (Itti, 2003; Rensink, 2000; Van Rullen, 2003), the perceptual system constructs the perceptual datum by identifying salient areas such as border, texture, the orientation of surfaces, the relations between figure and ground, and goes on to construct so-called proto-objects – volatile and roughly defined pre-attentive entities (Rensink, 2000). Thanks to this information, we are able to identify areas of greater informative density in a scene on a purely physical basis. Numerous computational models look for areas considered to be informative on the basis of certain physical parameters (*bottom-up*). One of the most convincing and best corroborated models has been put forward by Itti and Koch (Itti & Koch, 2000; Niebur, Itti, & Koch, 2001). In this model the attentive scanning of the scene is based on the creation of a map of salience. This map is drawn by extracting low-level elements organized according to color, intensity and position (but we might also add movement, borders and joins, the extraction of the shape of shadows, and several more). Another model is that put forward by Privitera and Stark (2000), which considers up to ten saliency factors-symmetry, spatial frequency, orientation, number of borders per unit of surface, entropy and contrast. The performance of this model largely corresponds to human scanpaths.

As Figure 4.1 shows, other aspects that can help to encode the layout of a scene are identified according to Gestalt principles and in general the potential – of the perceptual system – to build coherent objects and "good" shapes. Since the seminal works by Koffka (1935) and Wertheimer (1923), the perceptual priority of stimuli that were defined as "pregnant stimuli" or "near singularities" (Goldmeier, 1966) is well known. A recent study investigating the perception of some basic properties of the shape of an object by means of the change detection paradigm (Cohen, Barenholtz, Singh & Feldman, 2005) discovered that changes in the concave regions of a shape were detected more frequently than those in the convex regions because of figure-ground assignments. The authors interpreted their results regarding this differential blindness as a difference in the visual representation of the parts of an object and, namely, in visual asymmetries concerning the importance of the properties of a stimulus.

4.2 Change detection as a method for research into visual cognition

In recent years there has been a growing interest in a phenomenon which tests our "perceptual pride": so-called "change blindness" (Rensink, 2002; Simons & Levin, 1998). This term refers to the inability of observers to notice a change, even a very obvious change, which is introduced into a scene when a disruptive element is interposed between the first and the modified version. We should make it clear straightaway that this phenomenon not only occurs under rigidly controlled experimental conditions, but can also be reproduced in natural environments where interaction is real and dynamic.

For observers not to realize a change has taken place, some kind of mask or disruption between the original and the modified version needs to be used since, if the two scenes were presented without interruption, the change would be noticed without any difficulty as a transient or pop-out element (Simons, 2000). Interruptions are often caused by a blank masking field, according to the so-called flicker paradigm (Rensink et al., 1997). Other methods involve introducing a changed element when an observer blinks (O'Regan, Deubel, Clark & Rensink, 2000), during a saccade (Grimes, 1996; Henderson & Hollingworth, 2003), presenting mud splashes placed randomly across an image (O'Regan, Rensink, & Clark, 1996), during cuts in short films (Levin & Simons, 1997), in tasks involving the simple comparison of two images placed side by side (Shore & Klein, 2000) and even in real situations of interaction between two people (Simons & Levin, 1998; Levin, Simons, Angelone & Chabris, 2002).

Change detection is grounded on informativeness, since performance accuracy relies on early access to those parts of the visual field that convey the highest amount of information. We are tuned to be sensitive to relevant changes in our environment, which is why in the picture below we immediately see the change in position of the two people but we do not notice anything else.

Following this rationale, we can adopt the change detection paradigm as a method for investigating what is informative for our visual system. We claim that this method may be reliable in the study of this type of phenomenal aspect which, since the time of Gestalt psychologists, have been described as having a special status such as “singularity” or “good shape”. Can this method also be used in order to understand whether some visual relationships are more salient than others? For example, is change detection different (i.e. easier or more difficult) when the stimulus which changes is transformed into its contrary rather than into a similar or different stimulus? It is widely held that change detection performance improves as the magnitude of change increases. In other words, the more similar the post-change display is to the pre-change condition, the harder it will be to spot the difference (Mitroff, Simons, & Franconeri, 2002; Silverman & Mack, 2006; Smilek, Eastwood, & Merikle, 2000; Williams & Simons, 2000; Zelinsky, 2001, 2003; Ye & Yang, 2008). However, to our knowledge, this notion of “similarity” has never exhaustively been discussed and operationalized. Rensink (2002) goes into this more deeply when he describes those studies where changes are produced by manipulating one or more parameters such as orientation, size, shape and color (e.g., Palmer 1988; Grimes, 1996; Simons, 1996; Scott-Brown & Orbach, 1998).

Figure 4.2 Something changes in this picture other than the two people. Look behind the sphinx.

But their aim was to estimate the detection performance related to the kinds of change, rather than to the degree of similarity along the continuum of the same parameter. Other studies have demonstrated that change detection also depends on the magnitude of change in terms of conscious accessibility to the visual information on display (Carlson-Radvansky & Irwin, 1999; Smilek et al. 2000; Williams & Simons, 2000).

A more cogent approach to the manipulation of similarity has been proposed by Ye and Yang (2008) who manipulated both the conceptual and visual similarity of objects according to a rating method. In their study, a change may involve a combination of high and low, conceptual and visual similarities. They observed that the greater the similarity – either conceptual or visual – the better the performance would be. An attempt to manipulate and quantify the degree of change in naturalistic scenes was made by Simons, Franconeri, and Reimer (2000), their aim being to quantify changes in realistic scenes in terms of size contrast and color differences. These parameters were quantified according to a number of physical dimensions: size was measured in terms of the ratio of the changing region, in pixels, to the total size of the scene; contrast was calculated by comparing the changing region to the surrounding area; color was determined by transforming the scene form RGB to L*u*v coordinates and then assessing the distance of each pixel in the two versions of the scene. According to their results, the authors did not find significant correlations between detection performance and change magnitude, leading them to the conclusion that the awareness of change does not depend on the degree of dissimilarity between the two scenes, at least according to the three parameters they took into account.

A slightly different approach was proposed by Zelinsky (2003) who computed the degree of similarity in pre- and post-change objects in terms of color, orientation and size by adopting a filtering computational technique. His model accounted for change detection performance, since the degree of similarity was inversely correlated to change detection performance.

Manipulation of change has been an issue in another area of research, related to the change detection paradigm, namely the inattentional blindness phenomenon (Mack & Rock, 1998). It refers to the inability of observers to notice clearly visible events happening in their visual field while they are focused on an attention-consuming task such as visual search, object tracking and so on. The most famous demonstration of this phenomenon is in a video prepared by Simons and Chabris (1999). The task for observers was to count the number of passes of a basketball between three players in white shirts and to ignore the players with black shirts. Since the attentional set was tuned to avoid "black items" moving in the display, a lot of participants missed an actor passing through the scene wearing a gorilla suit. The participants who had been instructed to track the black team, had a higher probability of spotting the gorilla, since the color of the target stimuli (the players) and the unexpected stimulus (the gorilla) were quite similar. Therefore, as in the case of change detection, similarity seems to play a role in the awareness of events. An attempt to manipulate this similarity was proposed by Most, Simons, Scholl, Jimenez, Clifford & Chabris (2001) adopting more simple stimuli such as T and L-shaped objects, with a cross as the unexpected stimulus. The cross passed through the scene while observers were counting the bounces of either white Ts or black Ls. The cross could be white, light gray, dark gray or black. This manipulation allowed them to check for the similarity of unexpected items and stimuli. The results were quite clear: cross detection performance decreased according to the degree of similarity of the cross to the items to be ignored.

Similarity could be also manipulated in terms of shape as well as luminance. Most, Scholl, Clifford & Simons (2005) manipulated the similarities involving both shape and color and got similar results to Most et al. (2001). Moreover, they investigated this phenomenon with human faces: the trend was similar to that with objects. Paying attention to Caucasian faces and ignoring African American faces makes it hard to notice an African American face passing through the scene.

Revonsuo and Koivisto (2008) recently investigated whether inattentional blindness is due to the similarity between unexpected items and those which are to be ignored or to the dissimilarity between unexpected and expected items. By manipulating the shape and color of items, they came to the conclusion that inattentional blindness can be accounted for by referring to the attention set for target items, rather than to the active ignoring of non-target items.

As can be seen from this rapid glance at inattentional blindness and change detection literature, similarity has been considered as a critical issue in terms of understanding the cognitive dynamics of visual awareness, but: (a) similarity between pre- and post-change objects (or between expected and unexpected items in inattentional blindness) has often been manipulated according to assumptions on the part of experimenters regarding the phenomenal appearance of these types of changes; (b) the similarity has not been operationalized within the class of the various different types of relationships. All the examples presented above assume that the independent variable concerns only general judgments of similarity, but the relevance of similarity may be the result of analytical changes which are not of the same kind. For instance, it may be that when observers focus on the specific property/item which has been changed, they recognize contrariety rather than a variation in similarity. For example, if a cup changes into a glass of the same color, this can be considered as a variation of similarity, but if the glass is upside-down, while preserving the same relationship of similarity, this potentially becomes a relationship of contrariety.

We argue that a more accurate manipulation of these relationships would shed light on the phenomenon of "cognitive blindness", since, up to now, it has never been totally clear whether the construct of "similarity" adopted to account for change blindness has a solid phenomenal counterpart. In other words, we claim that change blindness occurs whenever pre- and post-change objects are very similar, but we are not quite sure whether these two instances would *actually* be judged as similar by observers involved in a rating study which is methodologically oriented towards experimental phenomenology. As far as we know from literature, changes have only been roughly operationalized and deserve more attention, since the implication is that all transitions from one instance to another involve similarity, difference or contrariety. Gestalt psychologists proved that relationships such as identity, similarity, causality, and figure-ground organization etc. are directly perceived by observers when looking at a scene, as are color, shape and size (for a review, see Bozzi, 1969 and Bianchi & Savardi, 2008a, p. 23 ff). The main hypothesis which Savardi and Bianchi's phenomenological approach to contraries is based on (Savardi & Bianchi, 2000; Bianchi & Savardi, 2008a, 2008b) is that contrariety is a self-organized perceptual structure in the same way as the other kinds of perceptual relationships mentioned above. To be more precise, the authors claim that it is a basic perceptual relationship, which is primal not only with respect to the organization of psychological dimensions (see Savardi, Bianchi & Kubovy, submitted) but also to the definition of similarity and difference, since these latter dimensions are also operationally defined by "local" contrarieties (see Bianchi & Savardi, 2008a; ch. 4, 5, 6). Since the time of the first research analyzing the similarity and diversity perceived between two objects, psychologists have studied whether the perception of one or the other relationship depended on the number of features that the two objects have in common. From the very first experiment conducted on similarity by Goldmeier (1936), this "quantitative" variable proved to be crucial, while at the same time not completely sufficient. A similar conclusion was at the heart of Tversky's (1977) contrast model which the author presented as a qualitative psychological model – as compared to metric models – to explain how similarity and diversity function in everyday cognitive, perceptual and linguistic applications. In this model, the role of quantitative aspects is clearly evident – and this aspect was still retained in its later formulations (Gati & Tversky, 1982, 1984, 1987; Markman & Gentner, 1993; Sattath & Tversky,1987). In all of these cases, similarity and diversity have, as critical factors, both the number of common and distinctive features and the salience of those common and distinctive features. A similar result was found by Savardi and Bianchi in a series of experiments using simple geometric figures (Savardi & Bianchi, 2000a, pp. 300-320; Bianchi & Savardi, 2006; 2008b; 2008a, pp. 115-130). The experiments demonstrated that people recognize contrariety as distinct from diversity and similarity and that two figures were perceived as contrary when they showed an evident contrariety in one or two characteristics while all other features remained invariant between the two figures. In this sense, the conditions for the recognition of contrariety seems to be more similar to those for the recognition of similarity than those for diversity, at least in terms of the number of features transformed. The studies proved in fact that an increase in the number of contrary properties does not produce an increase in the global degree of contrariety recognized. This kind of "summative" transformation was associated with the perception of diversity between two figures rather than of contrariety.

It was also found that not all the transformations which comply with this "numerical rule" (i.e. changing only one or two features) are adequate in terms of producing evident contrariety. In some cases the transformation, even though it consisted of a contrariety, e.g. the transformation of the surface of a shape from empty to textured, conserved the global identity of the two figures too well and participants in the study recognized the two figures as similar, not contrary.

These are the results emerging from a phenomenological analysis of these relationships, using different types of matched comparison tasks where in one experiment, participants were asked to rate the contrariety or diversity perceived using a minimum-maximum scale; in another experiment they were asked to classify each pair based on the relationship perceived between them – similarity, contrariety or diversity and in yet another task, participants were asked to rank 4 pairs of figures from the most to the least contrary.

But what happens if we direct the analysis of these three relationships away from this level of phenomenological analysis towards more constrained conditions in terms of time exposure and using a radically different task? More precisely, what happens if we analyze the "evidence" of these three relationships in a process of change detection?

On the one hand, if the number of features changed is the critical aspect, we might expect the change to be more easily detected when the substitution is with a "different" figure rather than with a "similar" figure or a "contrary" figure. On the other hand, if what emerges in this condition of short time exposure is not the invariant aspect of contraries but the fact that a maximal change along a dimension occurs, one might expect the change to be detected more easily when contrary figures are involved as compared to similar figures and even different figures.

4.3 The experiment

Nineteen undergraduate students from the University of Genoa (10 females, 9 males, age range: 23-40) participated in the study. All of them had normal or corrected-to-normal vision. Stimuli were taken from a previous study by Savardi & Bianchi (2008a) and consisted of a set of variations of an original figure. In figure 3 the original figure (top left) and its variations are shown. Each variation is made with reference to three parameters: dimension (small, large), orientation (0°, 90°, 180°) and shape (angular, rounded).

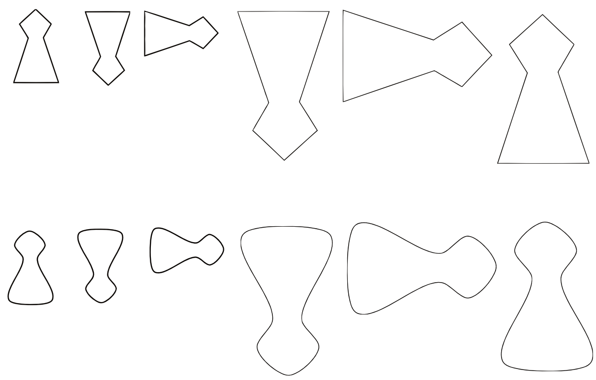

Figure 4.3 The figures used in the experiment.

The whole set of 12 items was arrayed according to the change detection paradigm: i.e. in each trial, a set of six stimuli was placed around a fixation cross, and each item was different from the others. A blank screen was then shown, and afterwards the same pattern was presented, but this time one of the six initial items had now been changed. The changes could be of three types: similar, contrary and different.

The changes were produced according to the phenomenal descriptions of the transformations in the studies mentioned in the previous section and were unequivocally recognized as different, similar or contrary (see also Figure 4.4). There were two kinds of transformation for each of the three categories, as follows:

1. similar: “single transformation” changes along the axis (e.g. vertical to horizontal, or 0° vs 90°; horizontal to vertical, or 90° vs 180°); “double transformation” a change in size (large vs small) and a in axis (vertical to horizontal or horizontal to vertical);
2. contrary: “vertical transformation” a change in direction along the vertical axis (0° vs 180°); “double transformation” a change in direction and a change in size (e.g. rotated through 180° and transformed from small to large);
3. different: “double transformation” change in both shape and size (e.g. from angular to rounded and from small to large); “triple transformation” change in shape, axis and dimension (e.g. from angular to rounded, from 0° to 90° and from small to large).

The three types of change were counterbalanced across positions of the figures in the pattern and for each kind of pre-change item. Since the changes could involve one or more features (e.g., the contrariety change could be a 180° rotation or a 180° rotation plus a change in dimension), 12 kinds of possible changes (similar, different, or contrary) were studied. Therefore, 12 kinds of change x 6 positions in the array x 12 figures resulted in 864 trials.

Participants performed six sessions of 144 trials each in order to cover the whole set of 864 trials. The dependent variables were reaction time (RT) and accuracy (i.e. the correct detection of the altered item). The whole experiment was run on a Acer laptop (Pentium M730), 17 inch screen, 60 Hz. The experiment was implemented on Adobe Air software. The procedure was as follows: participants were welcomed and invited to sit in a quiet, dimly lit room. They sat without any head constraint in front of the computer screen, at a distance of approximately 55 cm. They were instructed to look at the screen and spot the changed item. They were recommended to stare at the central cross during the whole trial and press the spacebar of the computer keyboard only when they were sure they had noticed a change.

Each trial consisted of a countdown of three seconds to warn the participant to look at the fixation cross. After that, an array of six different items surrounding the cross was flashed onto the screen for 400 ms, followed by a 200 ms blank screen after which the initial array was flashed for 400 ms, but now with one item changed (according to one of the three kinds of changes). Finally a blank screen followed for 200 ms and the cycle started again until the subject stopped the ongoing cycle by pressing the spacebar.

After stopping the trial, a set of six numbers corresponding to the six positions previously held by the items was displayed and participants had to click with the mouse on the position where they noticed the change (Figure 4.5).

When subjects chose the position where they supposed the change had occurred, a new trial began.

After 144 trials they could rest for 10 minutes before beginning a new session. Each session lasted about 25 minutes and the total number of sessions was six. After three sessions they could leave the laboratory and come back another day for the last three sessions. This was due to the highly demanding nature of the task that risked overloading the participants’ attention and biasing the performance due to fatigue. At the end of the experiment, they were debriefed and the purpose of the study was explained to them.

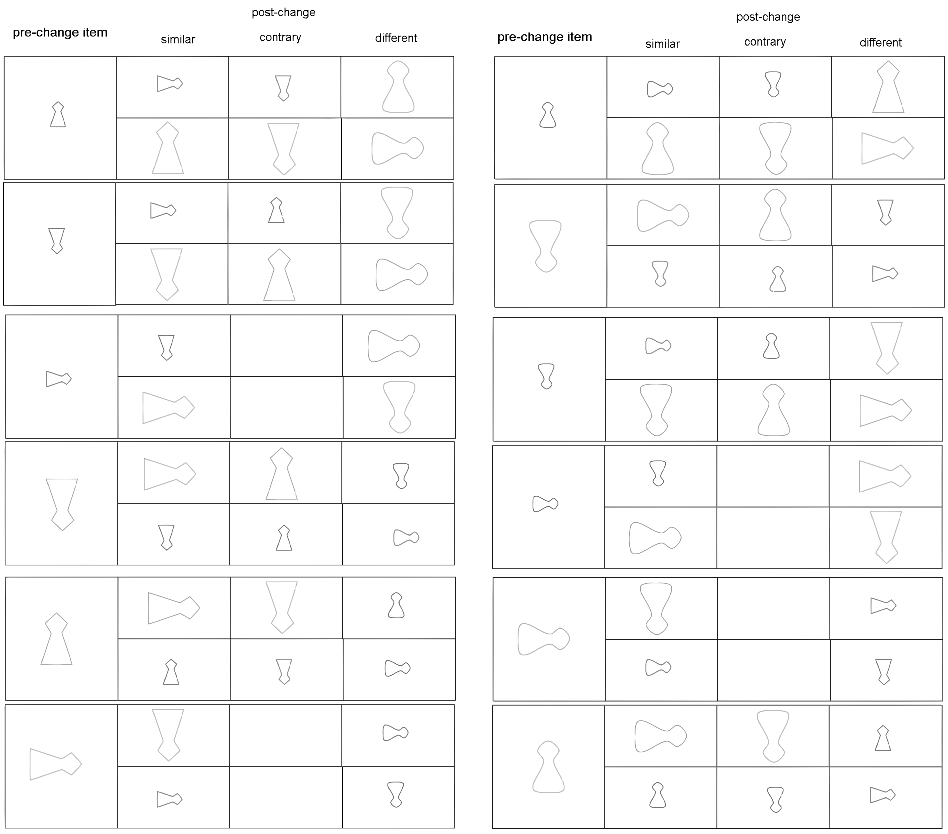

Figure 4.4 The changes adopted in the experiment. Left to right: similar, contrary, different. Each item has two instances of similar, contrary and different changes. Top row: single and double transformations; lower row: double or triple transformations. Some items do not have the contrary version since it was not produced in the previous rating study (Savardi & Bianchi, 2008a). In this experiment, these blank cells were randomly filled with the remaining items in order to complete the counterbalancing.

The participants underwent a training session before starting the experiment. The experiment lasted approximately 180 minutes.

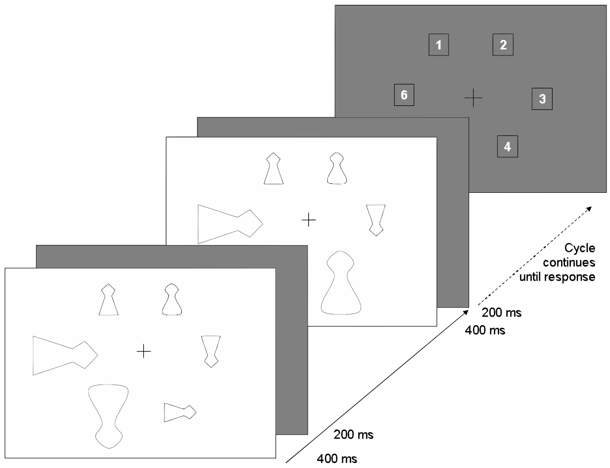

Figure 4.5 A sequence of a trial. The *original-modified* cycle continues until the participant responds

4.3.1 Results

We tested the association of the type of change with accuracy (Table 4.1) by means of hierarchical log-linear modeling (e.g., Knoke & Burke, 1988). The saturated model (i.e., the model of association) could not be rejected, since the interaction effect was significant ($G^2_{(5)}$=26.54, p <0.001), indicating that accuracy was associated with the type of change. Main effects were also significant. The significance of the main effect of the type of change ($G^2_{(5)}$=56.96, p<0.001) can be ascribed to the unbalanced distribution of the kinds of stimuli (see the Method section), while the significance of the main effect of accuracy ($G^2_{(1)}$=18790.33, p <0.001) was due to the overwhelming majority of detected changes. To further investigate the association of the type of change with accuracy, we computed log-linear cell parameters (λs). Lambdas are the ratios of the cell parameter estimates to their asymptotic standard errors. For large samples, these ratios can be interpreted as a standard normal deviate (*z* score), and the null hypothesis of a deviate equal to zero in the population can be tested. A deviate equal to zero means that the observed frequency and the frequency expected under the hypothesis of independence are equal. To control for the inflation of Type I error due to multiple tests, the significance level α was divided by the number of degrees of freedom of the table and further divided by two to obtain a two-tailed test. Given an experimentwise α=0.05 and that Table 4.1 has 5 degrees of freedom, the two-tailed critical value for the λs was 2.58 (p=0.005). The inspection of λs in Table 4.1 revealed that there were more undetected changes than expected under independence for the single transformation Contrary-Vertical condition, indicating that this kind of change was the most difficult to notice. The λ for detected changes of the Different-Triple-Transformation was not statistically significant after the correction for multiple tests, but its significance level (p=0.008) seems to suggest that this kind of change was the easiest to detect.

Table 4.1 Contingency table: type of change by accuracy

		Change						
Accuracy		**Cont-S-Tr (Vert)**	**Cont-D-Tr**	**Diff-D-Tr**	**Diff-T-Tr**	**Sim-S-Tr**	**Sim-D-Tr**	**Total**
Undetected	Count	58	39	32	32	55	64	280
	λ[1]	5.04	0.62	-1.34	-2.41	-0.95	-0.10	-64.66
Detected	Count	1775	2054	2282	2701	3582	3737	16131
	λ	-5.04	-0.62	1.34	2.41	0.95	0.10	64.66
Total	Count	1833	2093	2314	2733	3637	3801	16411
	λ	-0.96	-2.54	-2.93	-1.87	4.15	5.99	

We also analyzed reaction times (RTs) of trials with detected changes. At first, RTs were screened for outliers in each subject. RTs that differed by more than three standard deviations from the participant's mean were iteratively removed from the dataset until all the RTs were in the desired range of deviation. Mean RTs were computed for each participant in each condition and a one-way repeated-measure analysis of variance (RM-ANOVA) was performed. Since the sphericity assumption was violated (Mauchly's W=0.043, approximate $\chi^2_{(14)}$=50.49, p<0.001), the Greenhouse-Geisser (1959) correction to degrees of freedom was applied. As shown by Figure 4.6, the effect of the type of change was significant ($F_{(1.90,\ 34.10)}$=84.652, p<0.001, ω^2=0.11). Bonferroni corrected post-hoc tests revealed that in the Contrary-Vertical condition, which was the one in which the detection of the change was most difficult, mean RT was significantly higher than in all other conditions. Still consistent with the results of the log-linear analysis, the Different-Triple-Transformation condition was the condition with lowest RTs, indicating that this type of change was not only the easiest but also the fastest to be detected. Orthogonal contrasts were also performed to investigate differences between Contrary, Different and Similar transformations, independently of the variant of change. The three conditions significantly differed each other (t(34.10)=5.91, p<0.001), the Contrary conditions showed significantly higher RTs with respect to the other four conditions ($t_{(34.10)}$=8.30, p<0.001) and the Different condition showed significantly lower RTs with respect to the Similar condition ($t_{(34.10)}$=2.55, p=0.016).

[1] λ=log-linear model cell parameters. Values higher than |2.58| represent two-tailed statistically significant deviations of the observed frequency from the frequency expected under the null hypothesis of independence (after correction for the degrees of freedom of the table). Legend: Cont: Contrary; Diff: Different; Sim: Similar; S-Tr: Single Transformation (in column 3, the single transformation in question was a change along the vertical axis, in the up-down direction); D-Tr: Double Transformation; T-Tr: Triple Transformation.

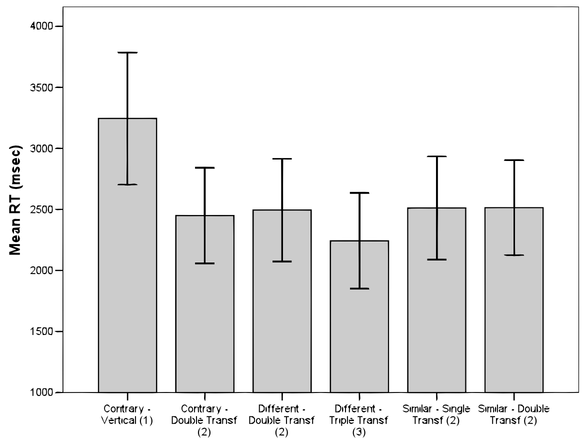

Figure 4.6 Mean reaction times (RTs) for each condition. Means of the conditions with different bracketed number significantly differ from each other.

4.4 Conclusions

The aim of this research was twofold:

1. to adopt the change detection paradigm as a method of investigating the perception of contraries;
2. to analyze how change detection performances vary according to the kind and degree of change when phenomenological categories (similarity, difference and contrariety) are used to describe the nature of the change.

The first objective originated from an interest in enriching already existing results from previous studies on the perception of contraries, based on phenomenological methods (Bianchi & Savardi, 2008). Change detection might in fact be an additional method of quantifying the information potential of various different kinds of transformations (Bracco & Chiorri, 2008).

The second objective was pursued using the knowledge derived from phenomenological research and focusing on whether two configurations are seen by participants as similar, different or contrary to each other, in order to establish the kinds of stimuli to be studied in a change detection task. As shown in the literature on change detection, the greater the change, the easier it is to detect it. However, the degree of change has seldom been operationalized and, to our knowledge, it is the first time that a change detection task presents changes which have been previously defined according to a phenomenological approach. The results from our study revealed significant differences between the three types of change: different, similar and contrary. In terms of the time needed by participants to detect the change, people were faster when the initial configuration was replaced with a *different* configuration as compared to a *similar* configuration. But the changes that required more time to be detected where those involving a *contrary* configuration. An analysis of the individual types of change suggested that the number of features changed in the stimulus, on the one hand, and the type of feature changed, on the other, are both critical factors. A single change of direction from up to down (contrary-vertical) was the most difficult to detect, whereas the easiest was the joint transformation of shape, size and axis (i.e. the different-triple transformation). These results emerged from both a log-linear modeling of the number of successfully detected versus undetected changes and a linear modeling of detection times. These results are in line with the literature on change detection, i.e. that the greater the change, the better the performance. The stimulus which was most easily detected was in fact the only stimulus, in our study, in which three features of the initial configuration (shape, size and axis) were changed. In all other cases, transformations concerned either one or two features. On the other hand, the transformation which was hardest to detect was a single transformation of orientation (from up to down). This is consistent with the characterization of change detection as an information-sensitive task: the amount of perceptual information regarding change was in fact richer in the former case and particularly poor in the latter. These quantitative criteria of the number of transformations seem generally to also be in agreement with the overall picture of our findings. The group of changes involving the transformation of two features was associated with intermediate reaction times. However, there was also another type of single transformation for which participants did not find as difficult to detect as the up-down single transformation, i.e. the change of the main axis of the figure from vertical to horizontal. This confirms our initial expectation that discontinuities in the detection of change performance might not only depend on the number of changed features but also on their type. So what is it about the up-down transformation which makes it so difficult to detect? In fact, this was a transformation that, as with the double transformation of direction and size, participants classified or rated as manifesting contrariety (rather than similarity or difference). We said in the introduction that the recognition of high invariance and at the same time of a maximal variation of the changed feature are both necessary aspects for two visual configurations to be perceived and described by naïve observers as contrary to each other. There is robust evidence of this emerging from various experimental tasks investigating the phenomenal aspect of visual configurations. Because of the invariance components which characterize the configurations used and classified as phenomenally contrary, one might expect that they would not be easily detected in a change detection task; in contrast, as a result of the maximal difference one would expect them to be easily detected. It is worth noting that predictions are much easier when similarity or difference are involved: in this case the perceptual aspect manifests mainly invariance in one case (similarity), and mainly variation in the other case (difference). But contraries are interesting precisely because of the simultaneous presence of both components. The high number of undetected changes and the long reaction times for the contrary configurations seem to suggest that it is the invariant nature of the two figures that emerges in this condition.

To interpret these results correctly, one needs however to consider that in the experimental conditions where a phenomenological description of the various configurations was obtained, participants were presented with only two figures which varied for one or more characteristics. The two figures were the only subject of the scene. They were not part of a more complex configuration made up of, for example, many figures; in this case, one of two transformations carried out on one figure would have involved only a part of the overall configuration. Moreover, perception was not constrained by short exposure time, but participants had as time as they needed to look at, explore and even inter-subjectively share the contents of their direct experience (when inter-observational sessions were used).

These are two important differences between the experimental conditions used in previous studies and those used in the study presented in this chapter. Here, in fact a) participants were exposed to the configurations for only a very *short time* and b) the transformation occurred in a *part* of the entire scene (which comprised 6 figures). Therefore the observation of a high number of undetected changes and long reaction times for this specific contrary configuration has to be understood in terms of the general conditions of perception presented here. In other words, in terms of information potential (Figure 4.1), it seems that a transformation of the direction in which a figure points from up to down – which we know has a high "information potential" in generating a perception of contrariety when applied to the entire configuration and not to only a part of it (and in prolonged exposure time conditions) – has in contrast a low information potential when it concerns a part of the configuration in a short exposure time. The same transformation, when associated with a transformation in size, maintains its "information potential" in generating a perception of contrariety when applied to the entire configuration and not only to a part of it (and in prolonged exposure time conditions) – but increases its "information potential" when it is part of a whole configuration and is presented with a short exposure time. On the other hand, a transformation such as a change of orientation from vertical to horizontal applied to a shape which clearly points in one direction, has a low information potential in terms of contrariety when applied to the entire configuration (and in prolonged exposure time conditions) and in fact people recognize it as producing a similar shape. It has a quite high information potential to be detected, however, when it concerns only a part of the configuration during a short exposure time. The data presented here are of course only an initial exploration in this domain. It seems, however, that applying change detection paradigms to phenomenology may be a promising approach in terms of enriching the investigation of the perceptual information contained in contrariety patterns.

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