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Colour appearance is affected not only by perceptual but also by linguistic context

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Terminology is a crucial problem in science, since quite often the terms used to denote theoretical concepts are directly taken from the vocabulary of common words, which usually have multiple meanings. To solve this problem, scientists must operationalize the theoretical concepts they use but, in psychology, sometimes, this can be a difficult task, since the meaning of the terms used to give the instructions to observers can interfere with the spontaneous meaning that observers give to those terms. Starting from some empirical observations, we show that colour appearance is affected not only by the perceptual but also by the linguistic context.

Key words: context, colour appearance, linguistic context

Experimental protocols used to interface specific theoretical questions to empirical evidence needs to be contextualized within a univocal linguistic framework. It is well known that theoretical concepts must be operationalized, that is, each concept must be defined by the measuring operations used. Within psychology studies, for example, the concept of hunger can be operationally defined as the number of hours of deprivation of food or as under-feeding. In this case, the terms "deprivation", "food", "under-feeding" have anunivocal linguistic meaning, but this is not always the case.

One who deals with visual perception has often to deal also with terminological problems. In fact, it often happens that lexicon does not include an appropriate term to name a certain perceptual phenomenon, even if it is simple, in terms of the number of spatial and temporal gradients. Quite the opposite, just the simplest situations, less articulated, are the ones that raise the terminological problems most difficult to solve. It is enough to think at *Ganzfeld*[1],that undeniably is the simplest stimulation condition in the visual domain, where the term used to describe the associated phenomenal experience is "fog". For example, a researcher intending to measure the perceived density of this fog as a function of the illumination will have to face the age-old problem of which instructions give to observers and, even before, the problem to operationally define "fog": "Please, compare this fog to this scale of fogs and tell me which one is the more similar". Then, it is possible to find that "subjects" in perception labs are able to perform whatever task is assigned to them, including a task of judging the size of an apple on a scale of pears, because, after all, each pair of objects has some common feature.

In this short account, we will talk about a study we have done to investigate grey surfaces perception under "ecological" conditions. With this aim, we identified some buildings having grey walls with reflective properties similar to those of a Munsell scale (Numerical scale of chroma devised by A.H. Munsell and exhibited in the Munsell Book of Colour), in such a way to be able to afford their reflectance values. We examined both interiors and exteriors surfaces. The most difficult part of the research was the experimental control of the illumination intensity that, being the natural

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1 An entirely homogeneous field, that is realized in such a way that the same quantity of light comes to the eye from each direction.

one, considerably varied as a function of the time and of the meteorological conditions. To compensate for this problem, we decided to collect the maximum possible observations in a short lapse of time. Therefore, for some days we went out always at the same time shouldering the photometer, we placed it always at the same distance from the surface on examination, and we measured its luminance. Straight afterwards we stopped people passing, mainly students, since the places we chose where inside Rutgers campus, and after placing them exactly at the same position where before the photometer was, we asked them to choose on a Munsell scale the grey that was more similar to the grey of the wall in front of them. In a Psychophysics experiment, when you want to measure a surface colour and not other different aspects like brilliance, compactness, etc., the experimental protocol provides that the instructions are given in the following way: "In front of you there is a surface. What you are asked to do is to choose on this scale the grey that, in your opinion, has been cut from the same material as the surface". In the latter case, the stress is put on colour and not on illumination. In certain cases, the same task can be formulated in a different way, by using, for example, a more common term, that is that of brightness: "Choose which one between those two surfaces is brighter" or "choose on this scale the grey that equate in terms of brightness the grey of that surface". The term brightness, however, in the common language, can denote both the surface colour and the perceived intensity of the light reflected by objects. In fact, it is possible to say both that an object colour is brighter than another object, and that a lighted area of the same object is brighter with respect to a shadowed area.

Two perceptual meanings, then, one tied to the reflective properties of the surfaces, and the other to the intensive properties of illumination. Another term introduced by Koffka (1935) to denote surface colour is whiteness. With this term Koffka referred to the quantity of white perceived in a certain blend of grey, therefore putting the stress on colour and not on illumination.

In a preliminary experiment we asked some observers to perform a task about colour perception, by using the three above-mentioned definitions. In the first case they had to choose from the scale the grey that was cut from the same cardboard as the target, in the second case they had to choose the one having the same brightness, and in the last case they had to choose the one having the same lightness. Independently from the kind of instructions, observers reported basically the same data. Therefore, as already said, despite the preliminary experiment did not show differences among the instructions, we decided to use the protocol that more explicitly refers to a matching on a colour level and not on that of the perceived intensity of the reflected light. Observers had to choose the grey on a Munsell scale and we wrote the corresponding number on a piece of paper.

However, there were some situations in which systematically a curious fact happened. Some of the walls that we had chosen for the experiment were, at the time of the day where we collected the data, partly in the shadow and partly directly exposed to the sunlight. In those cases, the observer was invited to choose from the scale a grey value both for the colour of the shadowed part and for the lighted part. The instructions made explicit reference to the surface colour and not to the reflected light perceived intensity; therefore, we expected that people involved in the task would show a certain embarrassment to make the choice. On the contrary, without showing any hesitation, they choose a light grey for the lighted wall and a dark grey for the shadowed one. Amazed by this result, we asked observers to look again the wall and tell us whether they perceived a surface having a homogeneous colour or a surface painted with two different colours, and which was/were the colour/s. All of them reported to see a homogeneously coloured wall (indicating also an almost correct shade), being partly in shadow and partly in light. This statement contradicted patently what they had done short before, that is to chose from the Munsell scale two different greys for the two areas of the wall. "What I see is a white wall, half in light and half in shadow". We insisted by asking which colour between that of the lighted part and the shadowed one was, according to them, more similar to the "true" colour of the surface. Also in this case without any hesitation all of them chose the one in light.

These observations then suggest that the parts of the same surface that are in light and those in shadow are seen as being of the same colour, but they are matched to different colours, and that the colour in light is more "veridical" than that in shadow. This means that the phenomenal experience of a very common experience like the one just described shows a complexity that it is difficult to reduce entirely in experimental terms.

What observers do when they choose two different greys for matching the lighted part and the shadowed one is to select greys on the basis of the absolute intensity that comes to the eye and not according to the luminance ratio with the background, as usually happens when the illumination varies and not the colour. The matching made on the basis of the absolute intensity of the light that hits the retina, known as luminance match, happens instead when, under homogeneous illumination conditions (that is, under conditions in which all the parts of an object are exposed to the same illumination), the colour of the object must be matched. The perceptual result obtained under these conditions has been named by Gilchrist type II constancy, to distinguish it from type I constancy, which appears when the colour is homogeneous and the illumination varies. Ross and Pessoa (see Gilchrist et al., 1999) renamed this distinction as illumination independent constancy (type I constancy) and background independent constancy (type II constancy).

Why, then, observers choose two different colours for the same surface and immediately after they acknowledge that it is not the colour to change but the illumination? Probably the formulation of the task diverted them. The instructions chosen for the experiment should favour a matching in the colour dimension and not in that of illumination. Come to think of it, however, to give instructions to observers to choose from the scale the grey cut from the same surface as the target area implies to assume that the illumination lack of homogeneity is not considered as an own feature of the surfaces. The shadow of a surface is something accidental for that surface. But this implication is not at all explicit in the instructions used. It is therefore likely that observers cut mentally a piece of the surface in light (bringing along also the light) and a piece of the surface in shadow (bringing along also the shadow) before deciding the grey of the scale that matches it. Maybe in this way it is possible to explain why a light can be matched to a colour.

Perhaps it is worth adding that the observers under these specific circumstances had little option, either they refused to make the task or they performed the match. According to what it has been reported as regards the higher veridicality of the colour in the lighted part of the surface, they might have made the match only for the lighted area. But this would have pushed them to partly violate the instructions.

As regards the second question, that is, whether the surface varied in colour or in illumination, the observers answered maintaining that they saw an unevenly illuminated homogeneously coloured wall, and they attributed to it a colour which was approximately the one corresponding to the surface reflective features. It is possible to assume that, in this case, the question suggested to the observers to spread attention on the whole wall instead on just a part, thing that would have permitted them to pick up crucial information for the correct attribution of both colour and illumination.

There is a number of cues that the visual system uses to recognize colour changes from illumination ones. For instance, penumbra seems to be a strong cue of change in the illumination dimension, even if in this respect there are different views (see Gilchrist, 1988; Soranzo & Agostini, 2004; Soranzo & Agostini, 2006; Soranzo, Galmonte & Agostini, 1999a; Soranzo & Agostini, 2006; Soranzo, Galmonte & Agostini, 1999b). But there is a factor that plays a critical role in shadow perception, that is, the kind of intersection between a reflectance edge and an illumination edge[2]. The intersection where an illumination edge crosses a reflectance edge has a property that can be called ratio invariance. It is important to underline that this property is not present when two illumination edges cross each other. In those cases, the ratios at the borders can noticeably change, but there is another kind of regularity, that is, difference invariance.

It seems likely that mathematical regularity at these intersections, which can be observed in natural scenes, guides perceptual organization of these scenes, edge classification included (Gilchrist, 1988).

To answer to the second question of our experiment, the observers had to spread attention, and this made them more sensitive to contextual factors and to regularities present in the environment.

Another factor that allows to distinguish reflectance changes from illumination ones, and that our observers can have used to answer to the question about the nature of the change, is the amplitude of the luminance ratio along the border. Katz (1911) noticed that luminance ratios produced by reflectance changes couldn't exceed the value of 60:1. A luminance ratio higher than that value can be produced only by a variation in illumination intensity. Koffka (1935) integrated Katz's observation in the organization principles stated by Wertheimer (1923). Perceptual organization principles are a set of laws that control the perceptual units' formation process. The parts that form a stimulus are organized by following structural relationships in such a way to give rise to the percept. Therefore, the percept is not the result of a sum or an association of the elements that make up the visual scene, but their structured unification on the basis of the laws of perceptual organization. For Koffka too, the structure of the perceptual field is so that luminance ratios exceeding 60:1 represent differences in the apparent intensity of the illumination. In the above-mentioned investigated cases, the luminance ratios were always higher than this value.

A point that is still to handle concerns the fact that all the participants said that the colour more similar to the "true" colour of the surface under observation was the one in light. The theoretical implications of this observation are noteworthy. In fact, one of the first theories proposed for explaining colour perceptual constancy refers to an unconscious inference mechanism, based on the "known" or "remembered" illumination (Helmholtz, 1868/1962). For Helmholtz, constancy derives from an unconscious evaluation, made by the visual system, of the illumination intensity, which is then used to compensate the actually recorded variations, in such a way to keep unchanged objects surface colour.

Katz (1935), following on from Helmholtz, underlines the fact that environment luminosity is something clearly visible, and among the various illuminations in which objects can be seen, only one has the nature of normal illumination, that of the empty air, in broad daylight, under clear sky. "True" colours of things are those that things themselves exhibit under this normal illumination.

Helmholtz and Katz's solutions to colour constancy problem are based on the distinction between "low-level" processes, that is, peripheral, retinal, physiological processes, and "high-level" processes, that is, central, cerebral, cognitive processes. Perceptual constancy will be due to the correction made by central processes on peripheral ones, in such a way to obtain a correspondence to "external reality".

2 Borders can be distinguished between reflectance edges, that is, an inhomogeneity in surface reflectance, and illumination edges, that is, an inhomogeneity in surface illumination.

Therefore, when an object is perceived as subject to a "non-normal" illumination intensity or colouring, there would be a tendency to transform perceived colour in the direction of the "true" one, that is, the colour that the object would show under "normal" illumination conditions. This reasoning assumes that the observers know which the "true" colour is, and that they are able to register the illumination independently from the object. Given that we have experience with objects placed under different illuminations, it can be assumed that their colour is known; therefore, when illumination is not normal, it is possible to deduct from context the true colour of the object through an automatic, and hence unconscious, inference, assigning the remainder to illumination. Such a process would be biologically oriented; to allow the individual to move in a world in which familiar objects are constant and do not change constantly in appearance (Kanizsa, 1975).

Although they knew nothing about perception, the participants in our experiment made the same assumption made by Helmholtz and Katz, that is, that the "true" colour is that of the objects exposed to a "normal" light, that is, sunlight. It would be easy to contradict this assumption by showing to our observers the Gelb effect (1929), which consists of the demonstration that, if a beam of light illuminates a black disk suspended in mid air in a darkened room, the black disk is seen as white. Therefore, in this case, assigning the "true" colour to the illuminated area would misguide them.

There is still one last observation to do. In our experiment, observers were immersed in an environment in which the mean illumination value was notably high, since almost all observations have been made outdoors in sunny days. This means that, in general, the impression was that of a highly lit environment. It would be interesting to see if the more "veridical" colour is always that of the most lit surface also under conditions in which observers are put in a penumbra situation, and only a small area of their visual field is illuminated by a beam of light coming from, for example, an aperture open outside, from which light beams filter. In other terms, it would be interesting to see if the quality of the predominant illumination is relevant in determining which one among the colours of the several surfaces present in the scene is perceived as more veridical. It could happen that, under penumbra conditions, the true colour would be assigned to things in the shadow instead of those in light.

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