Is Light Blue (*azzurro*) Color Name Universal in the Italian Language?

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Abstract. In the study of 1969 Berlin and Kay have argued that there are a limited number of universal "basic color terms" which are the same for each culture [1]. They postulate the existence of 11 basic color terms, including a single blue term. After Berlin and Kay's work, several researcher have tried to confirm or refuse this theory. Those successive studies led to two principal theories: universalistic [2] (confirming the Berlin and Key theory) and relativistic (refusing the Berlin and Key hypothesis) theories [3–6]. This papers brings a new argument in favor of the relativistic theory and provides some evidence on the existence of a twelfth color class in the Italian language. In particular, results support the hypothesis of the existence of an additional monoleximic color name for the class corresponding to light blue (*azzurro* in Italian language). This hypothesis is proved by using the Stroop effect, introduced in 1953 by John Ridley Stroop [7]. The Stroop effect is based on the analysis of the reaction time in a given task. Our claim is that when the name of a color (e.g., "blue," "green," or "red") is printed in a color which is not denoted by the name (e.g., the word "red" printed in blue ink instead of red ink), naming the color of the word takes longer and is more prone to errors than when the color of the ink matches the name of the color. Accordingly, we investigated the reaction time of Italian mother language speakers performing a Stroop task with both dark blue and light blue color. Results show that the reaction time is statistically different when the light blue is associated to the monoleximic color name *azzurro* than to monoleximic color name blue (*blu* in Italian language).

Keywords: Color perception, Color categories, Italian color terms, Cultural influence.

1 Introduction

When Berlin and Kay introduced basic color terms in their 1969 book "Basic color terms, their universality and evolution", a new way of thinking about colors and color terms had begun [1]. The predominant view of linguistic relativity gave way to cross-cultural color universals that could be identified for all languages. Since then, many studies investigated this issue either to support the universalistic theory [2] or to refuse it in favor of the cultural relativistic one [3–6]. Nevertheless, no agreement has been reached so far. The cultural relativistic

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view posits that color perception is greatly shaped by cultural specific language associations and perceptual learning. The universalist view is that panhuman shared color processing is the basis of color naming within and across cultures. The study of Berlin and Kay [1] rose the universal theory which claims that every culture would categorize all the colors in 11 classes (Red, Green, Blue, Yellow, Orange, Purple, Pink, Brown, Gray, Black and White). According to their definition, color terms are operationally defined as *basic* only if monolexemically named and psychologically salient for all speakers, but not if restricted to narrow classes of objects or included in the signification of other color terms. This theory received relevant support from subsequent studies [8, 2]. At the same time, the Berlin and Kay's theory received considerable criticism consequently to empirical evidence on the perceptual processing of color. This evidence includes the proof of considerable variation in color processing among individuals in the same culture, and new results on important cross-cultural differences in color naming and categorization [9]. Another relevant critique is the existence of single blue term in the universal theory. Some studies support the existence of two terms for blue in some culture. Greek, Russian and Turkish belong to this category [10–13].

Our claim is that Italian also have this feature. Previous results [14] have provided some evidence in support to the hypothesis that Italian subjects suffer the absence of the Italian color name for the light blue color (named *azzurro*). In this work, the subjects were constrained to use monolexemic color names from the eleven basic color categories identified by Berlin and Kay in a color naming task. In this way it was emphasized that for Italian subjects it is not spontaneous to classify the light blue color inside the blue color class. To get further evidence, another experiment based on the Stroop effect was designed and implemented, as described in what follows. Results show that the *azzurro* term holds has all the features of a basic color: it is monoleximic, it is used with high-frequency and it is agreed upon speakers of that language[1].

The paper is organized as follows. Section 1 summarizes the background, namely the Stroop effect. Section 2 describes the methodology and the details of the experiments that have been performed and introduces the results of each experiment. Section 4 derives conclusions.

2 Background

In 1935 Stroop [7] investigated color naming versus word reading, and hit upon the idea of a compound stimulus where the word was incongruent with the color. The two major questions were: (i) what effect each dimension of the compound stimulus would have on trying to name the other dimension? (ii) how would this affect the observed interference? Stroop developed two main experiments: in the first one the effect of incompatible colors on reading words aloud was investigate and in the second the task was switched to naming the colors aloud. This study proved that when the name of a color (e.g., "blue," "green," or "red") is printed in a color not corresponding to the name (e.g., the word "red" printed

in blue ink instead of red ink), naming the color of the word takes longer and is more prone to errors than when the color of the ink matches the name of the color. This accounts for the fact that naming colors can be slower than reading words. Moreover, the Stroop study proved that there was no interference from incongruent colors in reading words but there was highly significant interference from incongruent words in naming colors [15]. After many years the Stroop effect is still in use for different purposed, mainly in the clinical field (e.g., [16–18]).

Our claim is that in the Italian language the light blue color do not fall inside the blue color class. Instead, it falls inside an additional universal color class named *azzurro*. Naming a color takes longer if it is printed or rendered on a monitor in association to a non congruent color word. Consequently, our hypothesis is that naming a light blue color should take longer than naming a dark blue color if both are associated to "blue" color word. To demonstrate it, five experiments were performed. Different colors, extract from the Munsell system, were shown in both congruent and not congruent conditions (e.g. ,red color-red color word and red color-yellow color word).

The basic idea is to prove that naming a dark blue color needs shorter time than naming the light blue color if both are associated to the "blue" color word (*blu*). Similarly, according to our hypothesis naming a light blue color would need shorter time if it is associated to light blue color word (*azzurro*) than if it is associated to blue color word. Results support the hypothesis that two blue colors with the same Hue but different Value belong to two different color classes.

3 Methodology and Results

Five experiment are carried out in order to prove the hypothesis of the existence in the Italian language of an additional monoleximic color name for the class corresponding to light blue.

In this section, the methodology and the results are presented in separate subsections, one for each experiment: Experiment 1 (Control Experiment), Experiment 2, Experiment 3, Experiment 4 (Control Experiment) and Experiment 5.

3.1 Experiment 1: Control Experiment

In this test the subjects were asked to name freely, without constraints, the name of the color displayed on the screen. The color was shown as a string of "x". This allows to collect the names used by the subjects and thus to highlight the spontaneous use of the term *azzurro*.

During this test the reaction times were collected. These can be considered as a benchmark of naming time for simple colornaming, namely in absence of the linguistic influence of the color word. The subjects were completely blind to the goal of the experiment.

Methods. The experiment were implemented in Matlab by means of the CRS toolbox (http://www.crsltd.com/catalog/vsgtoolbox/index.html). The stimuli

were shown in a calibrated Mitsubishi Diamond Pro 320 display on a middle gray background in a completely silent dark room. Subjects answer were recorded using a microphone to automatically detect the onset of the speech.

The stimuli shown on the screen were of six different colors and were chosen from the Munsell color system. Specifically, the prototype for *azzurro* color was chosen at the same Hue of the dark blue color but at a different Value. The Munsell colors were converted in the RGB system to show them in the calibrated CRT screen. This set of colors included: red (*rosso*) [Munsell system: 7.5R 5/20], blue (*blu*) [Munsell system: 5PB 1/10] , yellow (*giallo*) [Munsell system: 5Y 9/12], purple (*viola*) [Munsell system: 2.5P 3/18] , pink (*rosa*) [Munsell system: 7.5RP 7/10] , and light blue (*azzurro*) [Munsell system: 5PB 6/14], in Italic the Italian color word.

These colors were chosen for two main reasons. First, except for the light blue color, all are universal basic colors. Second, a color was chosen for each step of the evolutionary pattern by Berlin and Kay [1], except for the achromatic colors which were not relevant to this experiment because of the chosen paradigm (it is very usual seeing names of colors wrote in black).

Our hypothesis is that light blue color is in Italian language a basic color. The idea consists in comparing different reaction times between dark and light blue with other different basic colors and color words based on the Stroop effect. The number of colors was bounded to six in order to limit the duration of the experiment.

A string of "x" was shown in one of the six different colors cited above. The use of a string of "x" was chosen because is perceptually similar to a string of letters composing a color word but do not have a semantic meaning. More in details, a string of characters composing the word "orange" have a semantic meaning while a string of "x" of the same length (e.g., "xxxxx") does not have any linguistic significance. A "xxxx" control was used also in past studies (e.g [19]). The number of characters composing the string was changed randomly at each trial to reproduce the changes in the number of characters of the words corresponding to Italian colors (e.g., 'xxxxx' to simulate the length of the name red in Italian language "rosso"). In this way we were able to perform another control experiment. This allowed us to check if the length of the string can influence the reaction time of the subjects in naming the color.

Subjects were asked to name the colors loud as quickly as possible. The subjects were free to use every color word. The stimulus was shown at the center of the screen subtending 10 degrees of visual angle. Data were collected in two sessions of 18 trials each. Six sessions were performed for each color. Between each stimulus, a middle gray image was displayed with a fixation point at the center of the screen. The rest time between the stimuli was set to 2 seconds, in order to avoid the post visual effect or effects of linguistic influence from the previous color or color word. Neill and Westherry ([20]) manipulated speed-accuracy instructions and inter-trial interval in Stroop experiment. The suppression effect was found to persist for at least one second; after 2 sec the effect was completely dissipated.

In this study, every time the subject gave an answer the researcher pressed a key on the keyboard to show the new stimulus. The answer was record by means of microphone and the time of the stimulus presentation was recorded. An acoustic bip at the start of the experiment was used to synchronize the two data flows for the audio and the reaction time recording respectively (WAVEform audio format and MAT-file). The reaction times are extract from the audio file automatically (http://www.fon.hum.uva.nl/praat/) which permits to detect when the subject is in silent and when the subject is speaking.

Subjects. Seventeen subjects (7 females and 10 males) aged between 21 and 31 participated in the experiment. All were blind to the goals of the experiments. The subjects had normal or corrected to normal vision and were tested for normal color vision (Ishihara test).

Results. The results of this experiment show that the average time required for naming a color on a string of "x" it is not significantly different for all the considered colors (ANOVA p-value$<$0.05). Noteworthy, the subjects used the term *azzurro* completely spontaneously for the light blue color. This could be an indication of the fact that this is a monolexic name and it is salient for all the subjects.

In figure 1 the median and the 25th and 75th percentiles of the reaction times are reported for all the colors.

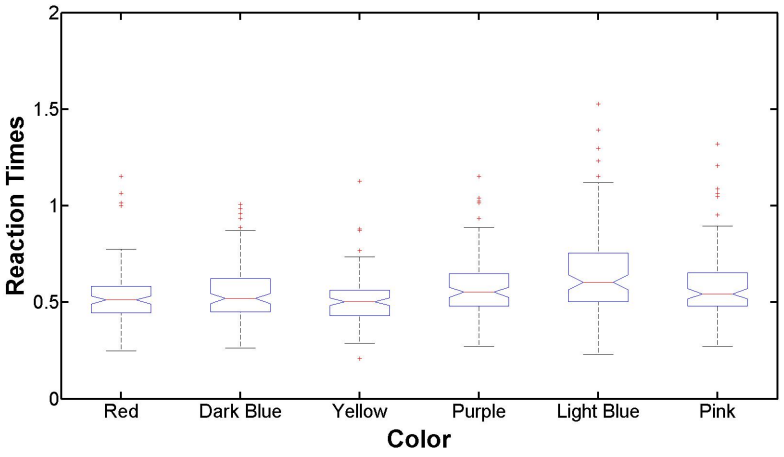


Fig. 1. The median and the 25th and 75th percentiles of the reaction times for each color of Experiment 1 are reported. The central mark represents the median, the edges of the box are the 25th and 75th percentiles; the whiskers extend to the most extreme datapoints not outliers, while the outliers are plotted individually.

3.2 Experiment 2

The second experiment was aimed at investigating whether reaction times are shorter for correlated color and color word (e.g., red color and red color word) than they otherwise (e.g, red color and blue color word). More specifically, the different reaction times between dark blue and light blue color on the color word blue (*blu* in Italian language) were tested.

Methods. The experimental set-up was the same as for Experiment 1 but the stimuli were different. In particular, the strings of "x" were replaced with real Italian color words. Four colors names were considered: red (*rosso*), blue (*blu*), purple (*viola*) and yellow (*giallo*), in Italic the Italian color word. The light blue (*azzurro*) and the pink (*rosa*) color words were not included. The first one was not included in order to avoid any influence on the subjects from the Italian color word *azzurro*. The pink color was not included to investigate if the reaction times for the light blue color could be due to consequence of the lack of the corresponding color word. In such case, the same effect would be observed for the pink color.

Data were collected in two sessions, totally six times for each couple of color and color word. The data were collect in two sessions to avoid the fatigue and practice and learning effects proved by Stroop [7]. For the same reason we preferred to collect data from more subjects without putting them under stress.

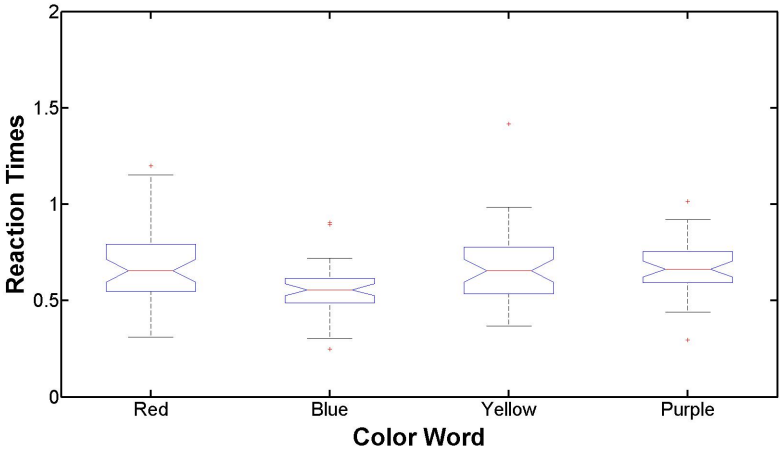
Subjects. Six subjects (2 females and 4 males) aged between 25 and 27 participated in the experiment. The same subjects were tested, first, for Experiment 1. All the subjects had normal or corrected to normal vision and were tested for normal color vision (Ishihara test).

Results. ANOVA test revealed that for all the colors, the mean of the reaction times are shorter when the name and the color are congruent. It could be useful to mention that the "corresponding" color words for the light blue and the pink color were not used in this experiment. For both of these colors (pink and light blue) the reaction times are not significantly different when they are associated to red, blue, yellow or purple color word. A difference could be observed for reaction times for both light blue and pink colors when associated to the blue word. However, but this was not statistically significant.

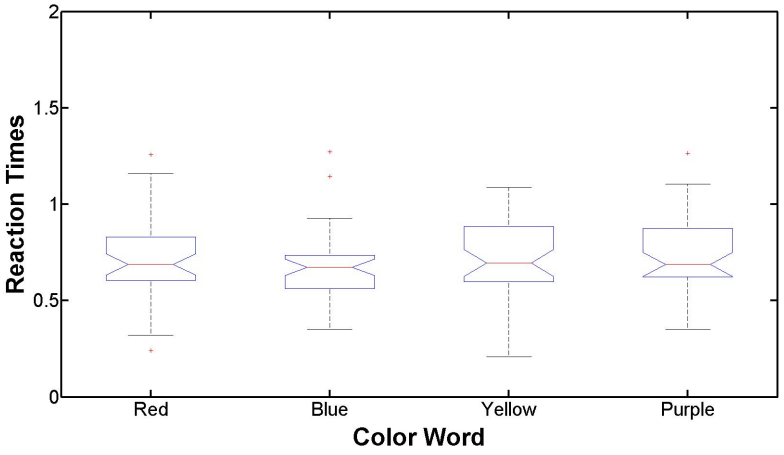
ANOVA test revealed that the mean reaction time of the these two colors (light blue and pink) when associated to all the considered color words are not statistically different. Instead, for the color that have the corresponding color word (e.g., red color and red color word) the difference is significant.

In figure 2 the median and the 25th and 75th percentiles of the reaction times are reported for the dark and the light blue colors when associated to any color words.

The t-student test showed that for each possible combination of stimuli (color and color word):



(a) Dark Blue Color



(b) Light Blue Color

Fig. 2. The median and the 25th and 75th percentiles of the reaction times for the dark and the light blue colors associated to any color words we used in Experiment 2 are reported. The central mark represents the median, the edges of the box are the 25th and 75th percentiles; the whiskers extend to the most extreme datapoints not outliers, while the outliers are plotted individually. The dark blue color have significantly shorter reaction time if associated to the blue color word than all the others color words (red, yellow and purple). No statistically significant differences are recorded for the light blue color in relating to the different colors words (red, blue, yellow and purple).

- the color word red have significantly shorter reaction time if associated to red color than for the other colors
- the color word blue have significantly shorter reaction time if associated to dark blue color than all the other colors (dark blue color: 0.556 sec; red color: 0.661 sec; yellow color: 0.669 sec; purple color: 0.745 sec; light blue color: 0.671 sec; pink color: 0.668 sec). This means that the subjects name more quickly the dark blue than the light blue color if both are associated to the blue color word
- the color word yellow have significantly shorter reaction time if associated to yellow color than all the other colors
- no statistically significant differences are recorded for the purple color word in relating to the different colors

The point here is that the blue color word corresponds to a mean reaction time that is shorter for dark blue color than for light blue color. The case of purple color word will be investigated in future work.

3.3 Experiment 3

In this experiment the color words for light blue (*azzurro*) and pink (*rosa*) were introduced. The main goal was to test the reaction times for the light blue color associated to the blue color word (*blu*) and to the light blue color word (*azzurro*), respectively. The same six colors and color words of the Experiment 1 were kept.

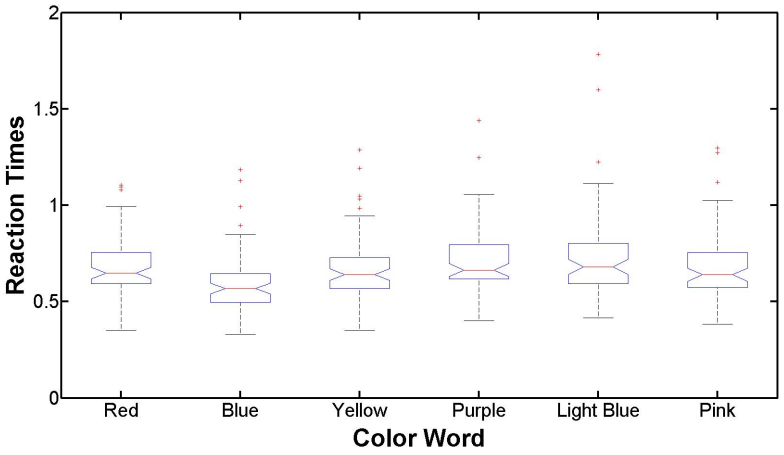
Methods. The experimental set-up was the same as for Experiment 2 except for the addition of the light blue and pink Italian color words. Six color words used were: red (*rosso*), blue (*blu*), purple (*viola*), yellow (*giallo*), light blue (*azzurro*) and pink (*rosa*). The colors and the color words were show in completely random order in two different sessions, six times for each couple (color and color word).

Subjects. The subjects that performed this experiment were naïve to the task. This was done in order to avoid practice and learning effects. Furthermore, this allows to avoid the biasing of the performance that could be reduced for the awareness of the use of the color word *azzurro* in previous tasks. 11 subjects aged between 21 and 31 participated in the experiment (5 females and 7 males). The same subjects were tested first for Experiment 1. All the subjects had normal or corrected to normal vision and were tested to prove their normal color vision (Ishihara test).

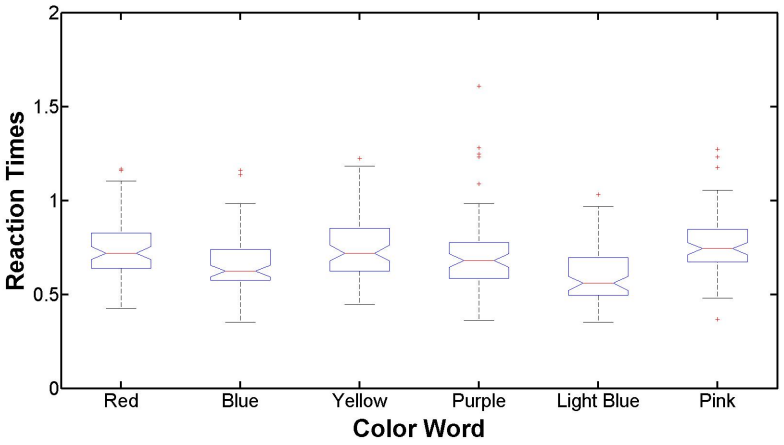
Results. ANOVA revealed that for all the colors, the mean of the reaction time is significantly shorter when the name and the color are congruent. Importantly, this also applies to the light blue color associated to the *azzurro* color word.

In figure 3 the median and the 25th and 75th percentiles of the reaction times are reported for the dark and the light blue color associated to all the color words.

By a t-student test for each possible combination of stimuli (color and color word) we found the same results as for Experiment 2 for the color word Red,



(a) Dark Blue Color



(b) Light Blue Color

Fig. 3. The median and the 25th and 75th percentiles of the reaction times for the dark and the light blue colors associated to any color words we used in Experiment 3 are reported. The central mark represents the median, the edges of the box are the 25th and 75th percentiles; the whiskers extend to the most extreme datapoints not outliers, while the outliers are plotted individually. The dark blue color have significantly shorter reaction time if associated to the blue color word than all the others color words (red, yellow, purple, light blue and pink). The light blue color have significantly shorter reaction time if associated to the light blue color word than all the others color words (red, blue, yellow, purple and pink).

Blue, Yellow and Purple. The new results are from the light blue (azzurro) and pink color words. In summary:

- the color word *azzurro* have significantly shorter reaction time if associated to light blue color than to all the other colors (light blue color: 0.601 sec; red color: 0.663 sec; dark blue color: 0.761; yellow color: 0.657 sec; purple color: 0.711 sec; pink color: 0.735 sec)
- the color word pink have significantly shorter reaction time if associated to pink color than all the other colors

In conclusion, our results show that naming a dark blue color needs shorter time than naming a light blue color if both are associated to the blue color word. Naming a light blue color needs significantly shorter time than naming a dark blue color if both are associated to the light blue color word (*azzurro*). Moreover, naming a light blue color associated to the light blue color word needs shorter time than associated at any other basic color word.

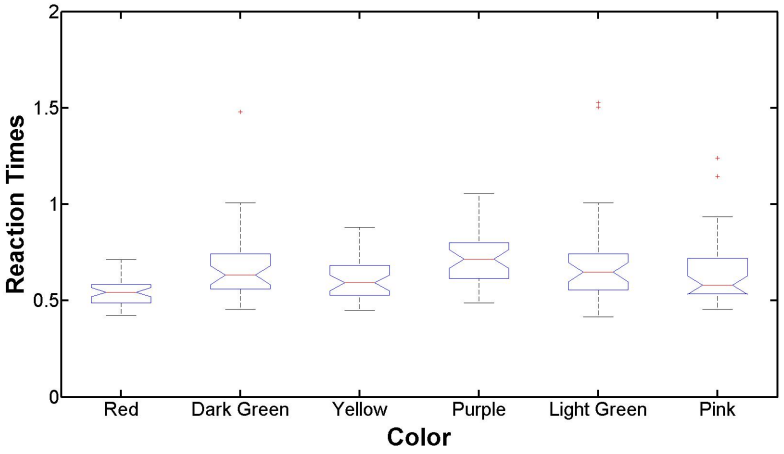


Fig. 4. The median and the 25th and 75th percentiles of the reaction times for each color of Experiment 4 are reported. The central mark represents the median, the edges of the box are the 25th and 75th percentiles; the whiskers extend to the most extreme datapoints not outliers, while the outliers are plotted individually.

3.4 Experiment 4: Control Experiment

Experiments 4 and 5 aim at investigating if the different reaction times between the dark blue and light blue color on the color word blue is a perceptual or a linguistic effect. To this end the dark and the light blue colors were replaced with dark and light green colors, respectively. Experiment 4 is a control test. The stimuli consisted of a string of "x", without any linguistic influence, colored with one of the six colors: red, dark green, yellow, purple, light green, pink.

Methods. The experimental set-up and the stimuli, as well as the number of trials, are the same as for Experiment 1. The only difference is in the colors. As mentioned above, both blue colors were replaced with two green colors. Both the blue colors have same Hue, but different Value in the Munsell color order system [dark blue, Munsell system: 5PB 1/10; light blue, Munsell system: 5PB 6/14;]. Similarly, both the green colors have the same Hue, but different Value [dark green, Munsell system: 10GY 1/10; light green, Munsell system: 10GY 6/14]. The difference in Value between dark and light blue colors is the same as between dark and light green colors. The task was to name freely, without constraints, the name of the colors on the screen.

Subjects. Six subjects (all males) aged between 21 and 29 performed the experiment. All the subjects had normal or corrected to normal vision and were tested for normal color vision (Ishihara test). As mentioned above a new group of subjects was selected to avoid the learning effect.

Results. This experiment shows that the mean reaction time to naming a color on a string of "x" it is not significantly different for all colors (ANOVA at a p-value$<$0.05). In this experiment both the blue colors were replaced with two green colors.

In figure 4 the median and the 25th and 75th percentiles of the reaction times are reported for all the colors.

3.5 Experiment 5

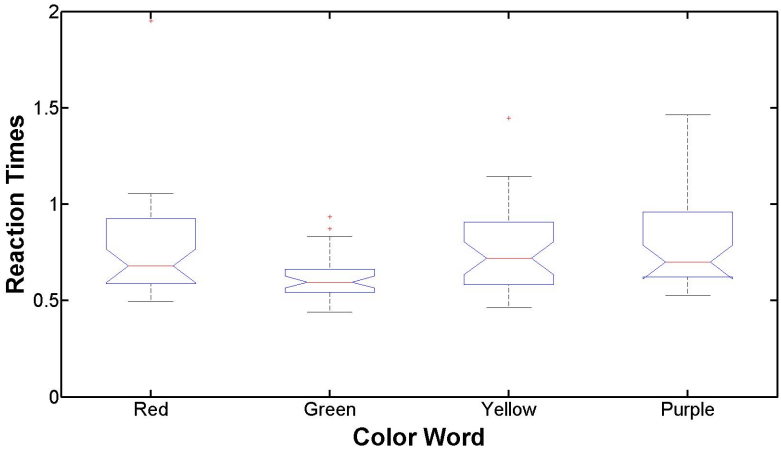
The objective of this experiment was to investigate if the results of previous experiments are driven by perceptual or linguistic effects. Our claim is that if the reaction time is the consequence of a perceptual effect then the same trend would be observed for both the blue and the green classes. Conversely, a different trend would support the linguistic hypothesis, since in this case the blue and the green classes would reveal a different underling mechanism ruling reaction time.

Methods. The set-up, the stimuli and number of trials of the last experiments were the same as for Experiment 2. The blue color word was replaced by the green color word. The two blue colors had the same Hue on the Munsell system but at two different Value. The green colors had the same Hue on the Munsell system and they are at the same difference of Value of the Blue colors.

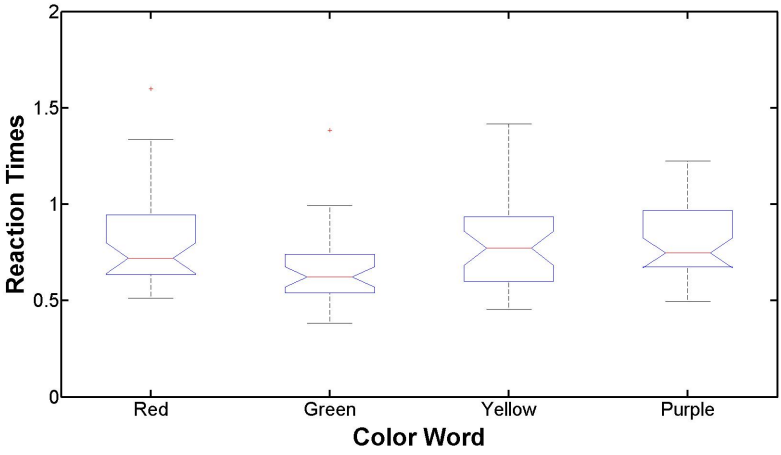
Subjects. The same subjects that participated in Experiment 4 performed this experiment.

Results. Testing by ANOVA shows that for red, yellow and purple the reaction times are shorter, on average, when the name and the color word are congruent.

Noteworthy, this experiment also shows that the reaction time of the dark green and the light green are both shorter if associated to green color word than to all the other color words. For the pink color the reaction time are not



(a) Dark Green Color



(b) Light Green Color

Fig. 5. The median and the 25th and 75th percentiles of the reaction times for the dark and the light blue colors associated to any color words we used in Experiment 5 are reported. The central mark represents the median, the edges of the box are the 25th and 75th percentiles; the whiskers extend to the most extreme datapoints not outliers, while the outliers are plotted individually. The dark and the light green color have significantly shorter reaction time if associated to the green color word than all the others color words (red, yellow and purple).

significantly different if associated to color word red, green, purple or yellow. The color word pink was not included as in the Experiment 2.

In figure 5 the median and the 25th and 75th percentiles of the reaction times are reported for the dark and the light green colors associated to all color words.

In this experiment the subjects named *spontaneously* both the dark and the light green color with the color word green; only one subject used the modifiers "light" and "dark" with the color word green.

By a t-student test for each possible combination of stimuli (color and color word) the same results of Experiment 2 for the color word red, yellow and purple were obtained. The new results are from the green color word. In summary:

- the color word green have significantly shorter reaction time if associated to light and dark green colors than if associated to all the others colors (red color: 0.724 sec; dark green color: 0.621 sec; yellow color: 0.71 sec; purple color: 0.874 sec; light green color: 0.67 sec; pink color: 0.773 sec). Both the reaction times are not significatively different if the green color word is associated to light or dark green color.

These results support the hypothesis that the different reaction times for the dark and light blue color associated to the blue color word are the consequence of a linguistic influence. In fact, the reaction times were statistically different when the subjects named the dark and the light blue color associated to the blue color word, but they were not statistically different when the subjects were naming the dark and the light green color associated to the green color word. Both the blue and the green couple of colors were at the same Value distance and the subjects used freely two different colors names for dark and light blue color while they use the same color word for dark and light green color.

4 Conclusions

The observed reaction times show that naming a dark blue color needs statistically shorter time than naming a light blue color if both are associated to a blue color word. Moreover, this work demonstrates that the reaction times are statistically shorter if the light blue color is associated to the *azzurro* color word than to the *blu* color word. Differently, the reaction times in naming a dark green and a light green color associated to the green color word are not statistically different. Furthermore, the experiments revealed that the subjects were using the color word *azzurro* spontaneously.

All this results support the hypothesis of the existence of an additional class in the blue region in Italian language and that this could be a consequence of a linguistic, as opposed to a perceptual, effect. Further experiments are currently being performed in order to prove such theory.

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