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Color makes a difference: Two-dimensional object naming in literate and illiterate subjects

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Abstract

Previous work has shown that illiterate subjects are better at naming two-dimensional representations of real objects when presented as colored photos as compared to black and white drawings. This raises the question if color or textural details selectively improve object recognition and naming in illiterate compared to literate subjects. In this study, we investigated whether the surface texture and/or color of objects is used to access stored object knowledge in illiterate subjects. A group of illiterate subjects and a matched literate control group were compared on an immediate object naming task with four conditions: color and black and white (i.e., grey-scaled) photos, as well as color and black and white (i.e., grey-scaled) drawings of common everyday objects. The results show that illiterate subjects perform significantly better when the stimuli are colored and this effect is independent of the photographic detail. In addition, there were significant differences between the literacy groups in the black and white condition for both drawings and photos. These results suggest that color object information contributes to object recognition. This effect was particularly prominent in the illiterate group.

Keywords: Illiteracy; 2D visual naming; Color processing

1. Introduction

An influence of literacy and formal education on object naming performance has been described in several experiments (Ardila, Rosselli, & Rosas, 1989; Kremin et al., 1991; Manly et al., 1999; Reis, Guerreiro, & Castro-Caldas, 1994; Reis, Petersson, Castro-Caldas, & Ingvar, 2001). There is a clear evidence that formal education and/or literacy influence the object naming performance of two-dimensional (2D) pictorial object representations. This is not the case for real (3D) objects (Reis et al., 1994, 2001).

The performance on simple object naming tasks is mainly dependent on the systems for visual recognition, lexical retrieval, and the organization of articulatory speech output, as well as the interaction between these systems [e.g., (Gordon, 1997; Levelt, Praamstra, Meyer, Helenius, & Salmelin, 1998)]. Reading and writing are dependent on advanced visual and visuo-motor skills in coding, decoding, and generating 2D symbolic representations. In the literate group of this study, learning and practice in interpreting schematic 2D representations often took place simultaneously with the acquisition of written Portuguese in school. It is therefore likely that the interpretation and production of 2D representations of real objects as well as the coding and decoding 2D material in terms of figurative/symbolic semantic content is more practiced in literate group compared to the illiterate group, which generally have received little systematic practice in interpreting conventional visuo-symbolic representations. We have previously observed (Reis et al., 1994, 2001) that the illiterate group was significantly better on naming colored photos compared to black-and-white (B and W) line drawings, and

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it might be asked whether the illiterate subjects can take advantage of additional information provided in the photos, such as color and photographic detail. Thus, the question is whether object naming in illiterate subjects is relatively more dependent on surface-based representations than on edge-based representations. In other words, does information about the surface texture and/or color of objects facilitate the accessing of stored object knowledge?

The discussion about the influence of color on object recognition has recently been raised in several papers [for a review see, (Tanaka, Weiskopf, & Williams, 2001)]. According to Tanaka et al. (2001), objects represented by color and shape might show a recognition advantage over objects represented by shape only in conditions where access to edge information is limited. In addition, it was demonstrated by Price and Humphreys (1989) that brightness/texture gradients (photographic detail) affect object recognition and naming. Other studies have found that appropriately colored objects are recognized faster than monochrome objects and inappropriately colored objects (Naor-Raz, Tarr, & Kersten, 2003; Price & Humphreys, 1989) or that color does not affect categorical judgments but the facilitation occurs in object naming tasks (Davidoff & Ostergaard, 1988). On the other hand, Bierderman and Ju (1988) argue that edge-based representations are crucial for object recognition and the objects should be recognized as easily when represented by edge information as when represented by other types of information (e.g., color photos, which contain surface information such as color, texture, and relative brightness). However, according to Sanocki, Bowyer, Heath, and Sarkar (1998), using a different conception of edge-based information, edge information is not sufficient for object recognition. Overall, these studies suggest that the function of color in object recognition is not well understood and there is no agreement concerning its role in object naming/recognition. Furthermore, there are some evidence suggesting that, at a lower visual processing level, color helps to differentiate objects (Gegenfurtner & Rieger, 2000; Wurm, Legge, Isenberg, & Luebker, 1993). For example, very brief presentations of natural scenes are matched more accurately by subjects when shown in color than when shown as luminance-controlled grey-scale images, which indicates that color provides an important source of information in the pre-recognition stage of visual processing (Gegenfurtner & Rieger, 2000). According to Gegenfurtner and Rieger (2000), color information contributes at both the sensory (coding) and cognitive (representation) levels of information processing for object recognition in natural scenes. More recently, Tanaka et al. (2001) proposed an object recognition model, the "Shape + Surface" model of object recognition. This model allows objects to be represented in terms of both their shape and color (and possibly texture), though it remains an open question at which processing level color is integrated with shape.

Additional evidence from patients with visual agnosia indicates that the visual characteristics of the stimuli (e.g., drawings/photos vs. objects) have an influence on the error pattern during object naming (Davidoff & De Blesser, 1993). For example, patients that show dissociation while performing object naming with drawings compared to real objects produce mostly visual errors, suggesting a deficit in the visual recognition system. If additional perceptual information is provided, then performance improves significantly. In contrast, patients that show no picture vs. object differences produce mostly semantically related errors, suggesting a deficit in language processing (Davidoff & De Blesser, 1993). Chainay and Rosenthal (1996) verified that color produced a significant effect on the patients' performance. In addition, they found that color facilitated the naming of natural categories but not artifacts, while color had no or little effect on object recognition. This categorical effect of color has been observed in several studies [e.g., (Price & Humphreys, 1989; Tanaka & Presnell, 1999)]. However, a recent study failed to replicate these findings (Rossion & Pourtois, 2004). Rossion and Pourtois (2004) collected normative data for Snodgrass and Vanderwart's object database of 260 B and W line-drawings (Snodgrass & Vanderwart, 1980). They then compared these data to data collected using the same shapes with gray-level texture and color added. Whereas, the addition of texture and shading without color yielded a slight improvement in terms of naming agreement scores, the addition of color information unambiguously improved the naming accuracy and speeded correct response times. This was observed for fruits, vegetables as well as man-made objects, with and without a single diagnostic (prototypical) color (Rossion & Pourtois, 2004).

Given our previous results on object naming performance in literate and illiterate subjects as well as the recent interest in the role of color in object recognition and naming, the primary objective of the present experiment was to investigate whether color information can be used synergistically to access stored object knowledge and benefit illiterate more than literate subjects. Specifically, we aimed to investigate whether there are differences in edge-based and color-based information processing of two-dimensional visual objects between illiterate subjects and literate controls. To this end, we investigated their immediate object naming performance on line-drawings and photos, presented either in color or in black-and-white (i.e., grey-scaled) in a fully randomized study design. Based on our previous results that demonstrated that the illiterate population has problems with decoding 2D representations compared to 3D representations (Reis et al., 2001), we predicted that illiterate subjects would benefit most from the additional surface-based information provided by the color compared black-and-white stimuli as well as by the photos compared to the drawings.

2. Materials and methods

2.1. Participants

In this study, we investigated the literate and illiterate population of Olhão in southern Portugal that we have been following for a number of years and where some subjects are illiterate for well-defined socio-cultural reasons [for a general overview of the selection procedures, see e.g., (Petersson and Reis, 2005, in press; Petersson et al., 2001; Reis et al., 2003)]. Briefly, in order to minimize the interference of other cultural factors, the illiterate subjects and their matched literate controls were selected from a similar socio-cultural background in a relatively homogeneous fishermen community of southern Portugal, where most of the subjects have lived most of their lives. The illiterate group consisted of 19 illiterate female subjects aged 61–75 (mean ± *SD*: 68 ± 4). The literate group included 19 literate females aged 56–83 (66 ± 8) and with a mean literacy level of 4.0 ± 0 years of education. The mean age difference was not significant. All participants had normal or corrected to normal vision and any kind of colour vision defects were excluded by the naming task of the neuropsychological test-battery used in the selection procedure, which included naming of colored objects (yellow, red, and green).

2.2. Stimuli and task procedures

The full set of items included 70 object representations (Supplementary Table), each well matched to a common everyday real object, selected from the set of Snodgrass and Vanderwart (1980). We chose common everyday objects for two reasons: to minimize possible vocabulary differences between subjects and the ease with which the drawings could be matched to similar real object to generate the photos. The real objects were chosen to be as similar as possible, both in terms of size and shape, to the line-drawings. A digital camera Fuji Finepix 601 with a 6-megapixel resolution was used to photograph each object in a colored version. Object orientation and size were matched to the line-drawing. The black and white version was derived from the colored one by applying Adobe Photoshop 7.0 "gray scale mode" command. All the 70 items were classified according to familiarity, visual ambiguity, and age of acquisition based on norms for the Snodgrass and Vanderwart set for the Portuguese population (Ventura, 2003). Visual complexity values were used from the original work from Snodgrass and Vanderwart (1980) (cf., Supplementary Table). Five different versions of each stimulus were generated: line drawings just constituted by the contours, black-and-white drawings (i.e., grey-scaled; DBW), color drawings (DCO), black-and-white photos (PBW) and color photos (PCO). Data collected using the line-drawing stimuli (contours) were not considered in the statistical analysis. The DBW (grey-scaled) and DCO representations were selected from the set generated by Rossion and Pourtois (2004) and correspond to the original Snodgrass and Vanderwart's set and are available online. Each stimulus for the DBW, DCO, PBW, and PCO conditions were presented in a 760 × 550 pixel format (cf., Supplementary Figure). The Presentation Software (http://nbs.neuro-bs.com/presentation) was used to display the stimuli on a HP laptop computer screen (size: 15"; spatial resolution: 1024*768 as the limiting resolution; color resolution: 24 bits) and to register responses as well as reaction times (RTs). Each stimulus was displayed for 5 s and voice detection equipment registered the RT between the on-set of the display and the on-set of the response. The 5 s display time was sufficient to name the items in each condition (Goodglass, Theurkauf, & Wingfield, 1984; Levelt et al., 1998; Salmelin, Hari, Lounasmaa, & Sams, 1994). All verbal responses were recorded with a tape-recorder. The 70 items were divided into 5 sets of 14 items each. For each participant five different sets of items were randomly chosen without replacement to be presented in one of the conditions. No subject saw the same object twice, to avoid the same object in two different conditions. The presentation order was identical for each group and randomized among subjects. Statistically, there was no significant difference between the sets for the variables previously described (familiarity, visual ambiguity, age of acquisition or visual complexity). The semantic categories were also randomly distributed between the five sets under the (soft) constraint that different items from the same category were allocated to different sets.

Before the experiment started, we used a specific set of items from each condition to ensure that the subjects were familiar with all experimental procedures and had a satisfactory understanding of the paradigm. The subjects were instructed to attentively view each item displayed on the computer screen, name the presented item as fast and accurate as possible using the most appropriate noun or otherwise remain silent. The responses for each object were pooled across conditions and the data from the DBW, DCO, PBW, and PCO conditions were submitted for further statistical analysis.

3. Results

3.1. Accuracy analysis

We first calculated the total scores of correct answers for each subject and each condition (Table 1). Data were analyzed with a repeated measures ANOVA with the following factors: presentation mode (drawings vs. photos), color attributes (grey vs. color) as within factors and literacy group as a between factor. The dependent variable was the mean accuracy while age was considered as a covariate. The analysis showed a significant literacy effect [$F(1,35) = 6.7$; $p = 0.01$], no presentation mode effect [$F(1,36) = 1.8$; $p = 0.19$], a significant effect of color attributes [$F(1,36) = 11.6$; $p = 0.002$], and a significant interaction between literacy group and color attributes [$F(1,36) = 5.2$;

Table 1
Means and *SD* from object naming performance (accuracy); maximum score = 14

Condition	Illiterates	Literates
Black-and-white drawings	11.26 ± 2.15	12.53 ± 1.26
Colored drawings	12.53 ± 1.31	12.95 ± 1.27
Black-and-white photos	11.74 ± 2.04	13.11 ± 0.81
Colored photos	12.63 ± 1.27	13.16 ± 0.99

Please note that black-and-white more precisely means grey-scaled.

$p = 0.028$]. This interaction indicates that the color effect was larger for the illiterate compared to the literate group (Fig. 1). The interaction between group and presentation mode was not significant as well as the interaction between presentation mode and color [$F(1,36) = 0.3$; $p = 0.57$; $F(1,36) = 0.5$; $p = 0.47$, respectively]. The three-way interaction was also not significant [$F(1,36) = 0.2$; $p = 0.69$]. Between and within groups, post hoc comparisons (Duncan Test) clearly show that the illiterate subjects benefited most from the color factor independent of the presentation mode. Specifically, there was a significant difference between groups for the black and white drawings ($p < 0.001$) and black and white photos ($p < 0.001$). In contrast, there was no significant difference between groups on naming colored drawings ($p = 0.25$) or colored photos ($p = 0.15$). Although the performance was slightly better in the literate group on color than on black and white stimuli, both for drawings ($p = 0.23$) and photos ($p = 0.87$), these differences were not statistically significant. For the illiterate group, the comparison between color and black and white stimuli was significant, both for drawings ($p < 0.001$) and photos ($p = 0.002$). Concerning the presentation mode, neither group did perform significantly better on photos compared to drawings on black and white (literates: $p = 0.11$; illiterates: $p = 0.52$) or on color stimuli (literates: $p = 0.55$; illiterates:$p = 0.76$).

These results clearly show that color, independent of the presentation mode, does make a difference for the illiterate subjects while this was not the case for the literate group. Interestingly, the illiterate subjects showed poorer performance on black and white photos compared to colored drawings ($p = 0.003$).

Finally, we performed an item analysis with a repeated measures ANOVA with the following within factors: literacy group (illiterates vs. literates), presentation mode (drawings vs. photos), and color attributes (grey vs. color). The results confirmed the previously described ones. The analysis showed a significant literacy effect [$F(1,70) = 21.0$; $p = 0.0002$], no presentation mode effect [$F(1,70) = 1.8$; $p = 0.19$], a significant effect of color attributes [$F(1,70) = 13.9$; $p = 0.0004$], and a significant interaction between literacy group and color attributes [$F(1,70) = 6.7$; $p = 0.01$]. Neither the interaction between group and presentation mode or the interaction between presentation mode and color were significant [$F(1,70) = 0.8$; $p = 0.4$; $F(1,70) = 0.1$; $p = 0.7$, respectively]. The three-way interaction was also not significant [$F(1,70) = 0.0$; $p = 1.0$].

3.2. Reaction-time analysis

In order not to confound group differences with performance differences, only reaction times from the correct responses were included in the analysis (81%). Reaction times for incorrect (7.2%) or no-answer (5.0%) trials were excluded, as were misregistered responses [software failure (1.5%), responses given outside the time window (1.0%), and responses anticipated by subject vocalizations other than the naming response (4.5%)]. The mean reaction times were calculated for each subject and condition. Data were analyzed with a repeated measures effects ANOVA considering presentation mode (drawings vs. photos) and color attributes (grey vs. color) as within factors and literacy group as a between factor and regressing out age effects. The results showed a significant group effect [$F(1,35) = 5.9$; $p = 0.019$], with the literate subjects having faster correct response times compared to illiterate participants. The remaining effects [presentation mode: $F(1,36) = 0.4$; $p = 0.54$; color attributes: $F(1,36) = 0.0$; $p = 0.88$] and interactions ($p > 0.28$) were non-significant.

4. Discussion

In this study, we investigated the hypothesis that object color facilitates performance on 2D object naming in

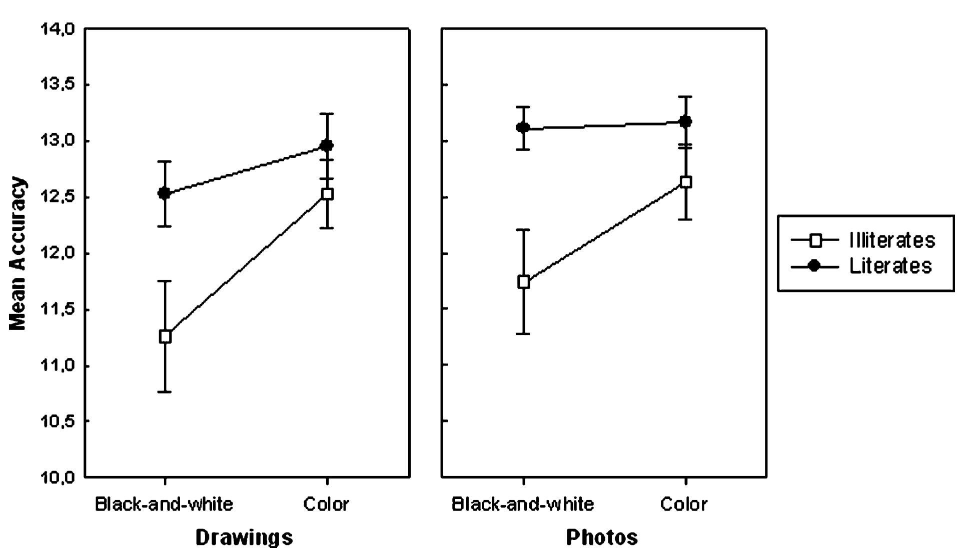

Fig. 1. Three-way interaction between literacy group and condition for naming performance (accuracy).

illiterate subjects. In a 2D object naming task with four conditions in a 2×2 design (color vs. black-and-white and drawings vs. photos), we compared the object naming skills of literate and illiterate subjects. The results demonstrated that for illiterate subjects, colored object representations significantly increased the 2D object naming performance independent of the presentation mode (drawings or photos). Both literacy groups performed similarly in color conditions while the illiterate subjects performed significantly lower compared to the literate group in the black-and-white conditions. This suggests that color has a stronger influence on performance than photographic detail for the non-literate subjects. This supports our initial hypothesis that for subjects with decoding difficulties (Reis et al., 2001), color facilitates object recognition and naming while texture provided by the photographic representation does not.

In our previous study (Reis et al., 2001), we suggest that a likely explanation for the differences between literacy groups in naming black and white 2D representations was related to the fact that the illiterate subjects have received no formal education and lack orthographic knowledge. The acquisition and systematic practice of the skill to analyze and decode 2D information typically occurred simultaneously with learning to read and to write during school attendance in this population. The lack of formal education implies that the illiterate subjects never had the opportunity to systematically learn and practice to process conventional 2D representations. In addition, regular reading and writing habits improve visual skills based upon 2D information (e.g., scanning 2D representations/2D pattern recognition).

We therefore suggest that literacy, entailing the acquisition and subsequent practice in processing 2D information, modulates the skill for naming 2D representations of real objects but has a limited effect on real object naming (Reis et al., 2001). Based on our previous results, we predicted an influence of color information and photographic detail and asked whether any of these factors could be used to facilitate access stored object knowledge. Our present results confirm our predictions with respect to color dependency and literacy. In particular, the results suggest that it is the presence of color attributes, independent of whether the stimulus is presented as a drawing or a photo, which facilitates the access to stored structural knowledge about objects. Although color increases the performance accuracy in the illiterate group, the naming latencies for correctly named the 2D items were longer for the illiterate compared to the literate subjects. This is consistent with previous results showing that the naming latencies for 2D representations are longer for the illiterate compared to the literate group, while the latencies for real objects are the same for the two literacy groups (Reis et al., 2001). Thus, it seems likely that the cause of the reported differences is either localized to the visual processing system, or the interface between the visual and language system during the process of accessing the name of the pictorial representation. In summary, although the illiterate group improves their performance accuracy on colored items, there is still a literacy effect on naming 2D representations in terms of response latencies. This latter effect appears to normalize only when the subjects name real 3D objects.

The role of surface based attributes on object recognition has recently been discussed. Surface (Marr, 1982) and edge-based accounts of object recognition make different predictions concerning the effects of surface information on object recognition. Surface-coding accounts predict that recognition will benefit if objects are depicted along with their surface details (such as variations in brightness, texture, and color). On the other hand, edge-based accounts predict that recognition of line drawings, containing reduced surface details, will be recognized as efficient as colored drawings and photos. Bierderman and Ju (1988) tested this hypothesis and concluded that color does not facilitate the recognition of objects when shape alone is sufficient. However, several studies have not confirmed these results. According to Nagai and Yokosawa (2003) and Tanaka and Presnell (1999), the results of Bierderman and Ju (1988) could be explained in part because the objects used in their experiments were only moderate to low in color diagnosticity. Recently, Rossion and Pourtois (2004) observed that the addition of texture and shading without color only yielded a slight improvement of naming agreement scores for the objects, while the addition of color information unambiguously improved naming accuracy and speeded correct response times. Also Naor-Raz et al. (2003), using a variation of the Stroop paradigm in which the observers named the displayed color of objects or words, suggest that color is an intrinsic property of an object representation at multiple levels. Another line of evidence about the potential role of color attributes in object recognition comes from ERP-studies. Proverbio, Burco, Zotto, and Zani (2004) investigated whether color was processed faster than shape information. The authors recorded the ERPs when volunteers selectively attended to either color or shape of familiar objects and animals. They observed that although the selection of color was dependent on object shape, but not vice-versa, the selection of color was faster than that of shape. Thus, there is a growing collection of results supporting an important role for color information in object and scene recognition (Gegenfurtner & Rieger, 2000; Nagai & Yokosawa, 2003; Naor-Raz et al., 2003; Proverbio et al., 2004; Rossion & Pourtois, 2004; Tanaka & Presnell, 1999).

As reported in several studies, illiterate subjects show lower performance on decoding 2D representations compared to 3D representations (Reis et al., 1994, 2001). This might be related to a lower capacity to code and decode edge-based information of abstract representations. Hence, it seems plausible that this group will potentially benefit most from additional stimulus information, for example color, in the process of visual segmentation and thus facilitate recognition. However, it is not well-understood at which visual processing level or levels color can come to play a role in object naming, an issue that needs to be addressed in future research.

5. Conclusions

In this study, we compared literate and illiterate subjects on coding and decoding 2D symbolic representations. Our results are consistent with the idea that color of objects contributes to object recognition by facilitating, in particularly the illiterate subjects, the discrimination of objects. The results also suggest that object naming benefits, albeit less, from photographic details like texture and/or brightness.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.bandc.2005.09.012.

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