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Revisiting Snodgrass and Vanderwart's object pictorial set: The role of surface detail in basic-level object recognition†

Bruno Rossion
Unité de Neurosciences Cognitive et Laboratoire de Neurophysiologie, Université Catholique de Louvain (UCL), 10 Place du Cardinal Mercier, 1348 Louvain-la-Neuve, Belgium;
e-mail: bruno.rossion@psp.ucl.ac.be

Gilles Pourtois
Donders Laboratory for Cognitive and Affective Neuroscience, Tilburg University, Warandelaan 2, PO Box 90153, 5000 LE, Tilburg, The Netherlands
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Abstract. Theories of object recognition differ to the extent that they consider object representations as being mediated only by the shape of the object, or shape and surface details, if surface details are part of the representation. In particular, it has been suggested that color information may be helpful at recognizing objects only in very special cases, but not during basic-level object recognition in good viewing conditions. In this study, we collected normative data (naming agreement, familiarity, complexity, and imagery judgments) for Snodgrass and Vanderwart's object database of 260 black-and-white line drawings, and then compared the data to exactly the same shapes but with added gray-level texture and surface details (set 2), and color (set 3). Naming latencies were also recorded. Whereas the addition of texture and shading without color only slightly improved naming agreement scores for the objects, the addition of color information unambiguously improved naming accuracy and speeded correct response times. As shown in previous studies, the advantage provided by color was larger for objects with a diagnostic color, and structurally similar shapes, such as fruits and vegetables, but was also observed for man-made objects with and without a single diagnostic color. These observations show that basic-level 'everyday' object recognition in normal conditions is facilitated by the presence of color information, and support a 'shape + surface' model of object recognition, for which color is an integral part of the object representation. In addition, the new stimuli (sets 2 and 3) and the corresponding normative data provide valuable materials for a wide range of experimental and clinical studies of object recognition.

1 Introduction

Visual object recognition is one of the most important functions of the brain, and accordingly one of the most studied in cognitive science. The visual system must recognize objects that usually have multiple features or attributes such as shape, texture, color, or characteristic motion, all of which can be used and combined by the visual system to elaborate object representations (Regan 2000). Theories of object recognition usually differ to the extent that they consider object representations as being based only on shape (eg Biederman 1987; Marr and Nishihara 1978), or if other object features such as surface details are also part of these representations (eg Tanaka et al 2001; Tarr et al 1998). On the one hand, 'structural' theories of object recognition emphasize the analysis of shape in object-recognition processes, largely ignoring color and other surface characteristics (eg Biederman 1987; Marr and Nishihara 1978). For instance, Biederman's (1987) recognition-by-components theory posits that objects are represented as an arrangement of simple, convex, volumetric primitives (blocks, cones, wedges, cylinders), which can be completely specified by the edges provided. Similarly, in Marr's theory of object recognition (1982; Marr and Nishihara 1978), surface gradients such

† A preliminary report of this study has been presented at *Vision Science* (VSS) 2001 (Rossion and Pourtois 2001).

as variations in brightness and texture are important for both the establishment of a primal sketch and the construction of an intermediate $2\frac{1}{2}$-D representation, but the complete 3-D object-centered representation consists of parts and spatial relationships derived from these cues to object shape (eg shape-from-shading). In other words, surface properties are 'discarded' from object representations. Consequently, these structural approaches to object recognition predict that adding surface properties such as color and texture will not facilitate recognition, in particular if the edges are already preprocessed, as in line drawings (see also Grossberg and Mingolla 1985). In fact, Biederman's theory of object recognition even suggests that object recognition should be more efficient for line drawings, which provide the visual system with preprocessed edges, than for realistically rendered pictures, from which the visual system must begin by finding the edges (Williams and Tanaka 2000; although see Sanocki et al 1998).

In contrast to edge-based theories of object recognition, image-based models of object recognition (eg Tarr and Bülthoff 1998) propose that objects are encoded as they appear to the viewer under specific viewing conditions. Thus, according to these models, object representations contain not only shape but also other cues such as surface information. Other approaches also favor a role of multiple cues in object recognition (Bruner 1957; Gibson 1969). However, none of these proposals explicitly formulates the role this information plays in object processing.

At the empirical level, the debate about the role of surface properties in object representations has been investigated in a number of studies that concentrated mainly on the influence of color in object recognition. Because these studies have led to conflicting results, the role of color in object recognition is currently still debated (Tanaka et al 2001): is color an integral part of perceptual object representation, or is it computed separately from the object-recognition system, and useful only when object recognition is ambiguous, as complementary semantic information ('color knowledge', eg "this picture must be a banana because bananas are yellow")? Early studies failed to find any advantage of color over black-and-white photographs in object classification and semantic tasks (Davidoff and Ostergaard 1988; Ostergaard and Davidoff 1985), nor between colorized photographs and simple line drawings in a naming task (Biederman and Ju 1988),[(1)] thus supporting the view that color is not part of the object representation (Biederman 1987; Davidoff 1991).

However, these results have been challenged by subsequent experiments that have reported a role of color in object-recognition tasks (Brodie et al 1991; Price and Humphreys 1989; Tanaka and Presnell 1999; Williams and Tanaka 2000; Wurm et al 1993). For instance, Price and Humphreys (1989) found that object naming was facilitated by congruent surface color and photographic detail as compared to line drawings, although the effects of these two variables were not additive. Moreover, in their study, the advantage of color and photographic detail were larger for structurally similar objects than structurally dissimilar objects.

These observations and others have led to the idea that color—and other surface information—play a role in object recognition only when color is highly diagnostic (Tanaka and Presnell 1999), or when shape is less diagnostic because objects share similar shapes (Price and Humphreys 1989; Wurm et al 1993). For instance, a number of fruits have similar shapes (orange, peach, apple, plum, etc ...) *and* have a diagnostic color. Hence, color can be a useful cue in recognizing these types of objects. Other types of objects, such as animals or some man-made objects (schoolbus, mailbox, etc ...),

[(1)] Although Biederman and Ju (1988) found a small but significant advantage in naming reaction times (RTs) for color photographs over line drawings in one of their experiments (unmasked conditions), they did not replicate it in masked naming and unmasked verification tasks, and concluded that simple line drawings can be identified about as quickly and as accurately as a fully detailed, textured, colored photographic image of the same object.

may have a diagnostic color but also have a highly diagnostic shape, and color is thus supposed to play a minimal role in the recognition of these latter cases (Biederman and Ju 1988). Color and other surface detail may also help when the diagnosticity of the shape is reduced because objects are degraded through occlusion (Tanaka and Presnell 1999) or in pathological conditions, such as low vision (Wurm et al 1993) and visual object agnosia (Mapelli and Behrmann 1997). Yet, it has been argued that these conditions are particular, and that color and other surface details do not play a role in basic-level object recognition, under normal viewing conditions ('everyday object recognition', Biederman and Ju 1988). Moreover, the studies in which the role of surface detail in object recognition was investigated had a number of limitations. For instance, they usually used very small samples of objects (eg Biederman and Ju 1988; Ostergaard and Davidoff 1985), and/or they compared line drawings to photographs, comparing similar but different shapes (eg Biederman and Ju 1988; Price and Humphreys 1989). To our knowledge, there has not been an experimental study testing systematically the respective role of texture and color in basic-level object recognition, for a large set of common objects belonging to different categories, with the exact same shapes.

The largest object databank currently available for experimental and clinical studies is a set of 260 line drawings of objects, provided with norms for name agreement, image agreement, familiarity, and complexity ratings (Snodgrass and Vanderwart 1980). The Snodgrass and Vanderwart (S&V) object databank is widely used in behavioral experiments with normal subjects on topics such as object recognition (for recent references, see eg Dell'Acqua et al 2001), naming (eg Pechmann and Zerbst 2002), attention (Pashler and Harris 2001), memory (Kohler et al 2001), or semantic priming (eg Damian 2000). The pictures are also used in single-case and group studies of neuropsychological patients with object recognition, semantic memory, and naming deficits (eg Berndt et al 2002; Ousset et al 2002; Ward and Parkin 2000). In a clinical setting, this set of pictures helps to disentangle the spared versus impaired abilities of patients presenting object-recognition and naming deficits (eg Graham et al 2001). These pictorial 2-D objects are also used in developmental studies (eg Brooks and MacWhinney 2000; Thomas et al 2001), normal aging investigations (eg Ardila et al 2000), and more recently they have also been used in neuroimaging (eg Op de Beeck et al 2000; Stark and Squire 2000) and electrophysiological studies (eg Harmony et al 2001; Van Petten et al 2000). The S&V picture set has been standardized in several languages such as Spanish (Sanfeliu and Fernandez 1996; see also Cuetos et al 1999), French (Alario and Ferrand 1999), and British English (Barry et al 1997); and Icelandic norms have also been recently collected (Pind et al 2000) for the set.

However, despite this widespread use, the S&V objects set is currently available only as drawings with reduced sources of information, ie without any surface details, such as texture, shading, and color, on the pictures (figure 1).

Here we created new computerized versions of the S&V stimuli using graphic software manipulations, adding detailed texture information and color. We then collected similar data for normative studies on French-speaking subjects, but on the 260 object pictures in a between-subjects design: line drawings, gray levels, and colorized stimuli. The role of texture and color in object recognition was assessed for the object-naming task by comparing the subject's naming agreements and mean reaction times (RTs) for the three sets of all pictures.

The objectives of our study were therefore twofold: (i) asserting the independent importance of surface details (texture and color) in basic-level recognition of a large standardized set of common objects, and (ii) providing a new databank of 2-D pictorial objects with surface details and comparative normative data, suitable for a wide range of behavioral, neuropsychological, and neuroimaging studies.

2 Materials and methods

2.1 *Subjects*

A total of two hundred and forty different subjects participated and were divided in 4 groups of sixty subjects for each task (naming task, familiarity, complexity, and imagery judgments). In each pool of sixty subjects, twenty were run under each condition (line drawings, gray-level, and colorized stimuli). Subjects were native French-speaking psychology students who participated in the experiment for course credits (age range 18 – 22 years). The sample was representative of the local population of first-year and second-year students in psychology at the University of Louvain (Belgium, French speaking), with most subjects being female (184/240). The sample was reduced to seventeen subjects out of twenty for each group for both the familiarity and the complexity judgments, and sixteen out of twenty for the imagery task, after removal of the subjects who missed some trials during the experiment.

2.2 *Stimuli*

2.2.1 *Preliminary work.* An important preliminary graphic work was performed on a Macintosh G3/300, before the coloring step, which consisted of editing and cleaning up strokes of the line drawings (as given in the appendix section of the original paper, Snodgrass and Vanderwart 1980). First, each picture ($N = 260$) was digitized at a high spatial resolution (600 dpi—8 bits per layer), resized, cropped, and centered with Adobe Photoshop 5.0 on a working sheet 10 cm high by 7 cm wide. Because of the poor visual quality of some of the original pictures, a fine-grained redrawing of the strokes was carried out with Adobe Illustrator 7.0. All pictures were saved in the PDS format (high-resolution Photoshop format) at 600 dpi in the gray-level mode, and the resolution of each picture was then reduced from 600 to 72 dpi (screen resolution) for the experiments. The pictures were centered on a rectangle of 281×197 pixels. The 260 pictures obtained from these preliminary computer-assisted operations constituted the original black-and-white version.

For each black-and-white picture (600 dpi), a modified picture adapted to the coloring step was systematically created by adapting the thickness of the strokes and lines, correcting some errors (eg missing parts or parts poorly defined in the original version), and defining as well as stressing visual details. According to the quality of the original picture and its inherent visual complexity in terms of the number of lines, two different strategies were adopted to efficiently prepare each picture before the coloring step: for almost 25% of the pictures (eg items such as an arm or a chair) the adaptation work was as described above without further changes, while for the remaining 75% (eg items such as an accordion or a barn), a new drawing was created. In this latter case, three different graphic methods were used: (i) from the PDS picture, a vector image was first created (Adobe Streamline 4.0) in order to render the fundamental structure and strokes of the pictures, which were retouched and rectified (Adobe Illustrator 7.0). (ii) The redrawing was made from the original picture, which was used as a mask in the background, to guarantee the best similarity possible between the original picture and the newly created one. (iii) A mixed bitmap/vector image was directly created in Adobe Photoshop 5.0 with the use of the mask technique such as that described in the previous point.

2.2.2 *Coloring.* A professional graphics artist created the texture and color versions of the original databank (a time-consuming process: in total 780 h, with a mean time for each picture of 3 h). To obtain relevant and correct color and texture information for each picture, the graphics artist used several encyclopaedic books available in most of the western countries, offering many visual examples and illustrations of the objects

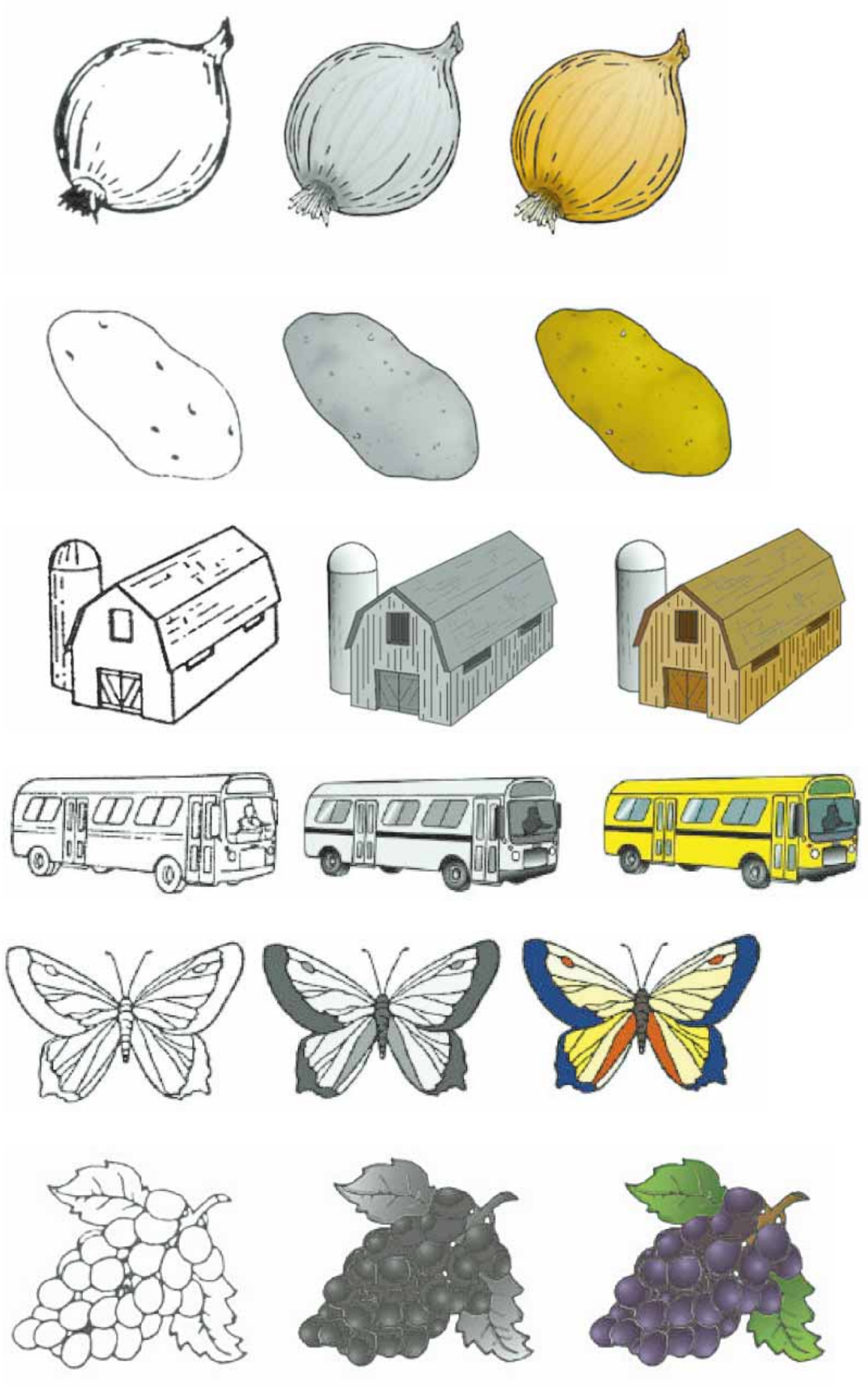

Figure 1. Examples of stimuli in the three conditions (original line drawings, gray levels, colorized from left to right, respectively).

presented in the databank.[2] During this computer-assisted work, color information and texture information were concurrently added.

Coloring and texture processing were mainly carried out with the different graphic tools (eg pen, paintbrush) available in Photoshop 5.0, as well as by manipulating and applying different filters in the millions of colors available in Photoshop 5.0 (eg adding structured noise, strengthening the strokes) and sometimes specific filters (eg texture explorer, glass lens) from Metacreations KPT (versions 2.1 and 3.0). All pictures were saved in two formats: PDS, to allow high-resolution printout and a low-resolution 72 dpi format (PCT) to be displayed on a screen. The 260 pictures obtained from these computer-assisted operations constituted the color version. The gray-level version (with two formats again: PDS and PCT) was obtained from the color version by removing color information in Adobe Photoshop 5.0 [ie the RGB mode for each picture was replaced by the gray-level mode]. Examples of the 3 sets of pictures are shown in figure 1, including 4 examples of pictures which had to be redrawn with the procedures described in this section, for accurate addition of surface detail. The whole set of pictures is available online (http://www.cog.brown.edu/~tarr/stimuli.html).

2.3 *General procedure*

2.3.1 *Naming.* Subjects performed the naming task individually. They were randomly assigned to one of the three conditions, and then presented successively with the 260 objects on a Macintosh AV17 computer with Superlab (Cedrus Corporation Inc). Each image was preceded by an attention signal (!) for 1500 ms, and lasted until either the subject's vocal response or 3000 ms had elapsed. After the subject's response or the 3000 ms delay, a blank screen of 1500 ms preceded the next trial. Subjects were told to name each picture as briefly and unambiguously as possible by saying only one name. Their responses were recorded by a microphone. They were told to respond "no" if they did not know the name, or if they knew it but could no longer remember it ('on the tip of the tongue'). In addition, subjects were asked to respond as soon as they recalled the name of the object.

2.3.2 *Familiarity.* Groups of twenty subjects each performed the complexity and familiarity tasks in a classroom. At the start of the experiment, they were told the importance of the experiment for collecting normative data and encouraged to respond carefully and consistently, without being influenced by the responses of other subjects. Stimuli were presented in the same order for all conditions, projected on a large screen from a Macintosh computer.

Each stimulus was preceded by an attention signal (!) for 500 ms and, after a brief blank screen (150 ms), was presented for 3000 ms. Subjects recorded their responses on individual data sheets. They were instructed to respond to every stimulus, leaving no blanks. Subjects were asked if they had completed their responses before the next presentation was started.

The instruction and procedure for responses matched exactly the original S&V study. Subjects were asked to judge the familiarity of each picture "according to how usual or unusual the object is in your realm of experience". Familiarity was defined as "the degree to which you come in contact with or think about the concept". They were told to rate the concept itself, rather than the way it was drawn. A 5-point rating scale was used in which 1 indicated very unfamiliar and 5 indicated very familiar. In this and all rating tasks, subjects were told to assign only one whole-number value to each picture and were encouraged to employ the full range of scale values throughout the set of

[2] The Reader's Digest Association 1984, *ABC's of Nature* Brussels, Belgium; Éditions des Deux Coqs d'Or 1970, *Le Grand Livre des Animaux* Paris, France; Le Soir 1998, *L'Encyclopédie visuelle: les animaux* supplement, Brussels, Belgium; National Geographic France 1998, *National Geographic: les dernières étendues sauvages* Paris, France.

pictures. Subjects were shown the first 30 slides in the sequence to allow them to anchor their scales (the same procedure was used for visual-complexity judgments below).

2.3.3 *Visual complexity.* Subjects were instructed to rate the complexity of each picture on a 5-point scale in which 1 indicated very simple and 5 indicated very complex. Complexity was defined as "the amount of detail or intricacy of line in the picture". They were told to rate the complexity of the drawing itself rather than the complexity of the real-life object it represented.

2.3.4 *Agreement between pictures and mental images.* Twenty subjects in each of 3 groups did the imagery agreement tasks individually. They were randomly assigned to one of the three conditions, and then presented successively with the 260 objects on a Macintosh AV17 computer. An attention signal (!) was presented for 500 ms, followed by the visually presented name of the picture (as determined from data of the name-agreement task), 3000 ms of blank screen, and then the picture for 3000 ms. During the 3000 ms blank-screen period, subjects closed their eyes and formed a mental image of the object named. Following the appearance of the picture on the screen, subjects rated the degree of agreement between their image and the picture using the 5-point scale. A rating of 1 indicated low agreement, that the picture provided a poor match to their image, and a rating of 5 indicated high agreement.

2.3.5 *Color diagnosticity.* To analyze the role of color separately for objects presenting a diagnostic versus non-diagnostic color, we collected a color diagnosticity score for each item on a 5-point scale, from eleven independent subjects (seven females, four males, mean age 24 years). Each colorized item was presented for an unlimited time (self-paced) and subjects had to rate the item according to the following instruction: "give a score between 1 (the color of the object depicted is not diagnostic at all, ie this object could be in any other color equally well) and 5 (the color depicted is highly diagnostic of the object, ie the object appears only with that color in real life).

2.3.6 *Data analysis.* For the naming task, several variables were recorded and/or computed: the most frequent name, the percentage of subjects giving this most frequent name, as well as the mean RTs, and standard deviations (SDs) for this name (when it was given first). In addition, the statistic H, reflecting the percentage agreement score taking into account the number of different names given for an item, was computed for each item in each condition (Snodgrass and Vanderwart 1980). The formula used was identical to that used in the original paper:

$$H = \sum_{i=1}^{k} p_i \log_2 \frac{1}{p_i} ,$$

where k refers to the number of different names given to each picture and p_i is the proportion of subjects giving each name. Multiple names were not allowed and only the first one was counted.

A picture that elicited the same name from every subject in the sample who was able to name it has an H value of 0 and indicates perfect name agreement. An item that elicited exactly two different names with equal frequency would have an H value of 1.00. Increasing H values indicate decreasing name agreement and, generally, decreasing percentages of subjects who all gave the same name. However, the H value captures more information about the distribution of names than does the percentage agreement measure. For example, if two concepts are both given their dominant name by 60% of the subjects, but one is given a single other name and the second is given four other names, then both concepts will have equal percentage agreement scores, but the first will have a lower H value. Accordingly, we shall use the H value as the primary measure of name agreement in subsequent analyses.

Analyses of variance (ANOVAs) were conducted on the mean H and RT measures. These values were extracted for the whole set of items, and also computed separately for different subsets of the pictures (animals, fruits/vegetables, body parts, man-made objects, and unclassified). For RTs, both subject analyses (factorial ANOVAs) and item analyses (repeated-measures ANOVAs) were conducted. Similarly to previous object-naming studies on large data sets (eg Barry et al 1997; Snodgrass and Yuditsky 1996) a subset of 169 items was selected for RTs. That is, the RT analyses were conducted only on the measures for the most common label given, only if more than 75% of the subjects agreed on this label for all three conditions. All RTs longer than 2 SDs of the overall subject's mean were removed. Familiarity, complexity, and imagery scale ratings were summarized by mean and SD values, and nonparametric statistical analyses were performed to assess any differences among the three picture conditions.

3 Results

3.1 *Naming task*

The following information for each picture can be found in appendix 1 (available online at http://www.perceptionweb.com/misc/p5117/): the identifying number and most frequent English name (as in the original study), two measures of name agreement (percentage accuracy and H values), the mean RTs for naming each item, and the most frequent name in French.

3.1.1 *General analyses.* The percentage of correct naming was high in all conditions (line drawings: 88%; gray levels: 89.3%; colorized: 90.7%; see table 1). For all items, the most common name was identical in all three conditions. The H values were lower for gray-level and colorized stimuli, reflecting an improvement of the subjects' agreement for the labels of the stimuli (table 1). The repeated-measures ANOVA performed on these values showed significant differences among the three conditions ($F_{2,518} = 12.85$, $p < 0.001$). A posteriori t-tests showed a lower H value for gray-level stimuli than original line drawings ($p < 0.05$), and a further advantage of colorized stimuli over gray-level items ($p < 0.01$). The difference between colorized and original stimuli was highly significant ($p < 0.001$) indicating lower H values in the former case than in the latter (table 1, figure 2). Thus, the addition of texture increased naming agreement among subjects, and color further improved these naming judgments (see figure 2).

Table 1. Summary statistics (means, Ms, and standard deviations SDs) for the naming task.

	Agreement scores, H			Accuracy rates/%			RTs/ms		
	line drawings	gray levels	colorized	line drawings	gray levels	colorized	line drawings	gray levels	colorized
M	0.44	0.38	0.32	88.2	89.2	90.3	882	883	804
SD	0.56	0.52	0.46	17.1	17.2	16.9	72	112	97

A one-way factorial ANOVA by subject carried out on the mean RTs showed a significant effect of surface detail ($F_{2,57} = 4.55$, $p = 0.015$). A posteriori t-tests (Tukey) indicated significant effects of color, the colorized pictures being named faster than line drawings ($p0 = 0.32$) and gray-level items ($p = 0.029$). The repeated-measures ANOVA by items was highly significant ($F_{2,336} = 24.43$, $p < 0.0001$). A posteriori t-tests did not indicate any significant difference between line drawings and gray-level stimuli ($p = 0.60$), but there were clear effects of color, with significant differences between gray-level and colorized stimuli ($p < 0.0001$), and between line drawings and colorized stimuli ($p < 0.0001$): on average, subjects were almost as fast to name line drawings as gray-level textured objects, but the addition of color reduced RTs by almost 100 ms compared to line drawings (figure 3).

These analyses indicate that, overall, the addition of color information clearly improved the agreement between subjects in the naming task, and significantly speeded up their responses, whereas the sole addition of texture compared to line drawings appeared to improve only naming agreement.

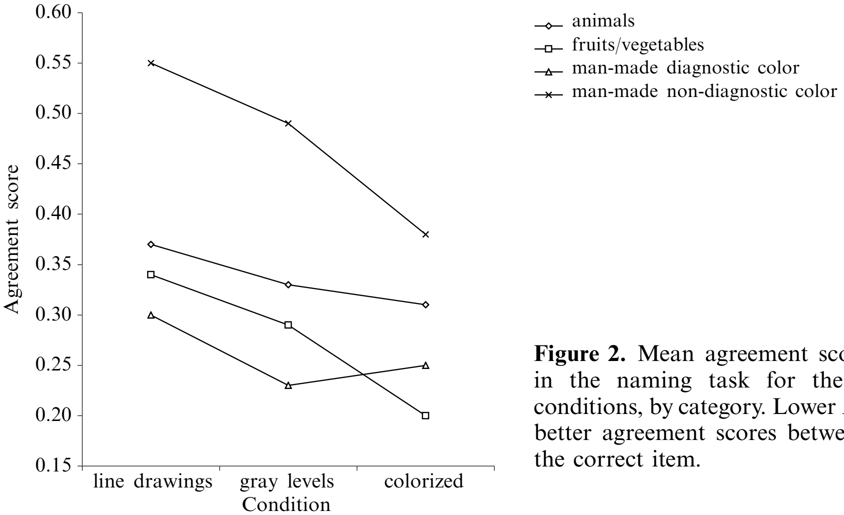

Figure 2. Mean agreement scores (H values) in the naming task for the three surface conditions, by category. Lower H values reflect better agreement scores between subjects for the correct item.

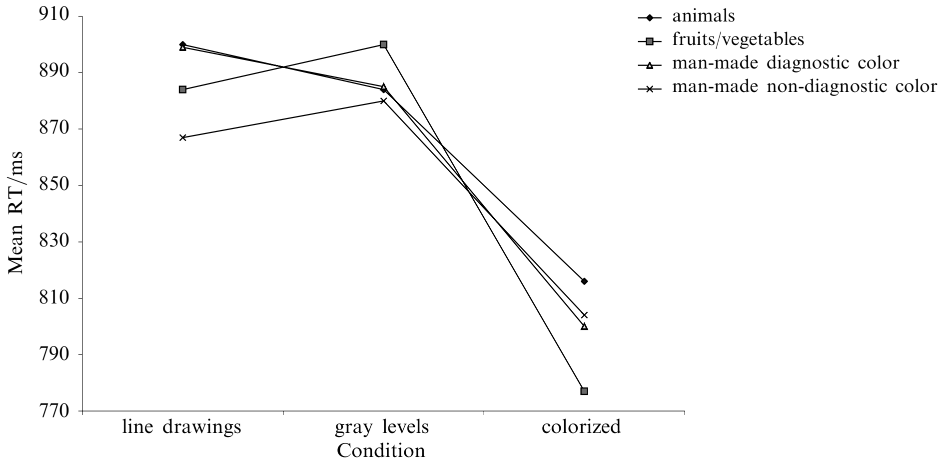

Figure 3. Mean naming response times for the three surface conditions, by category.

3.1.2 *Analyses with 'category' as a factor.* Because it has been argued that texture and color might only help object recognition for objects more likely to have diagnostic color such as fruits and vegetables, or animals (see section 1), the whole set of items was divided into three relevant categories: animals, fruits and vegetables, and man-made objects. On the basis of the results of the color diagnosticity measures, this latter category was divided into two subcategories: man-made objects presenting a diagnostic color, versus man-made objects not associated with a diagnostic color. The median color-diagnosticity score for man-made objects (2.63) was used to split the whole set of these objects into 2 groups. Table 2 presents the summary statistics (means and SDs of H and RTs) separately for the four categories (fruits/vegetables, animals, man-made diagnostic objects, and man-made non-diagnostic objects), in the three conditions.

Table 2. Summary statistics for the different categories of the naming task. A few items could not be included in any of these categories (body parts + mountain, star, moon, hand, cloud, sun, clown, arrow).

	Agreement scores (*H* values)			RTs/ms		
	line drawings	gray levels	colorized	line drawings	gray levels	colorized
Animals						
M	0.37	0.33	0.31	901	884	816
SD	0.46	0.43	0.46	97	112	99
Fruits/vegetables						
M	0.34	0.29	0.20	884	900	777
SD	0.47	0.41	0.37	90	105	106
Man-made diagnostic color						
M	0.30	0.23	0.25	899	885	800
SD	0.50	0.38	0.40	78	119	104
Man-made non-diagnostic color						
M	0.55	0.49	0.38	867	880	804
SD	0.61	0.57	0.49	77	114	100

A two-way factorial ANOVA with the factors surface details (three levels) and category (four levels) was conducted on the *H* values. There was a highly significant main effect of surface details ($F_{2,472} = 9.72$, $p < 0.001$) and a significant effect of category ($F_{3,236} = 3.19$, $p < 0.05$), but no interaction between the two factors ($F < 1$). The effect of surface details was mainly due to lower *H* values (better intersubject agreement) for colorized items compared to line drawings ($p < 0.0001$) and gray-level pictures ($p < 0.05$). The difference between gray-level pictures and line drawings failed to reach significance ($p = 0.08$). The main effect of category was due to man-made non-diagnostic color objects presenting higher *H* values than all other categories (paired comparisons: all ps < 0.05).

The two-way factorial ANOVA on RTs by items showed a main effect only of surface details ($F_{2,310} = 18.93$, $p < 0.0001$), due to faster responses to colorized items compared with gray-level pictures ($p < 0.0001$) and line drawings ($p < 0.0001$); the latter two conditions did not differ significantly ($p = 0.80$). There was no interaction between surface detail and category, suggesting that the advantage provided by color did not differ across categories. The analysis by subjects confirmed the main effect of surface detail ($F_{2,57} = 5.64$, $p < 0.01$; color versus gray-level pictures, $p < 0.01$; color versus line drawings, $p < 0.01$; gray-level pictures versus line drawings, ns). The effect of category was marginally significant ($F_{3,171} = 2.54$, $p = 0.06$) owing to slightly slower responses to pictures of animals than other categories (figure 3), and significant only when these pictures were compared to man-made objects without a diagnostic color ($p < 0.05$). However, most importantly, this analysis revealed a significant interaction between the factors surface details and category ($F_{6,171} = 3.23$, $p < 0.01$). Regarding the effect of texture alone (gray-level pictures versus line drawings), it was not significant for any of the categories tested (all ps > 0.5), but contributed to the interaction between surface details and categories, appearing to slightly speed up the responses to animals and man-made objects with a diagnostic color, but slowing down the other two categories (figure 3). Yet, the interaction between surface detail and category in the ANOVA was mainly due to a larger effect of color (versus gray-level pictures) for fruits/vegetables compared to each of the other categories (versus animals, $p < 0.01$; versus diagnostic color man-made objects, $p < 0.05$; versus non-diagnostic color man-made objects, $p < 0.01$). The effect of color was also significant for all categories tested separately (fruits, $p < 0.001$; animals, $p < 0.05$; diagnostic and non-diagnostic color man-made objects, ps < 0.05) and did not differ between the other three categories ($p = 0.4$).

To sum up the results, the addition of texture alone on the S&V object data set slightly improved the naming agreement among subjects (figure 2), but did not speed up their (correct) naming responses. On the other hand, the addition of color on these pictures also improved subject's agreement scores, but, most spectacularly, it speeded up naming response times. This was true for all categories, but particularly for fruits/vegetables (figure 3). The fact that the interaction between color and categories appeared in the analysis by subject but not in the analysis by items may suggest that the effects of color were observed on a majority of subjects, but for a subset of items for each category (see below).[3]

3.1.3 *Correlation measures, the role of texture and color.* Complementary analyses were run to better understand the role of color on a large subset of the S&V pictures. Color diagnosticity was further analyzed through a correlation analysis, over the whole set of items, between the diagnostic-color values (appendix 5, available online at http://www.perceptionweb.com/misc/p5117/) and the advantage provided by color alone in RTs (colorized picture RTs versus gray-level picture RTs). There was no correlation between these two measures ($r = 0.05$). When this analysis was run separately for each category, again no correlations were found between diagnosticity measures and the advantage provided by color (all rs < 0.2).

It has been suggested that surface details could affect object recognition and naming, especially for objects that were named slowly (Biederman and Ju 1988; Price and Humphreys 1989), and there was indeed a highly significant ($r = 0.69$, $p < 0.001$) correlation between the RTs to name line drawings and the advantage (in RTs) provided by the addition of color information. However, it is conceivable that objects that are already named quickly as line drawings will benefit only mildly, if at all, from the addition of texture and color information, and it may not be very informative to show that mean naming RTs of line drawings correlates with the gain provided by the addition of color and texture as compared to line drawings. The role of color alone was also assessed by testing the correlation between the mean RTs for naming line drawings with the difference between RTs for color-object naming and gray-level pictures. In doing this, we found a significant correlation of 0.31 ($p < 0.001$), showing that color reduced (after the addition of texture) the naming RTs more for the pictures that were named more slowly as line drawings. However, other evidence indicates that color improved object naming even for those items that were named the fastest in line drawings. For instance, considering only the 60 fastest-named items as line drawings (all < 805 ms) in a repeated-measures ANOVA with the three conditions showed that there was a significant difference between the sets ($F_{2,118} = 43.95$, $p < 0.001$) with color objects being named faster than line drawings ($p < 0.001$). And this was observed even though the ranking was based on the name latencies for line drawings! However, texture did not speed up the naming of these pictures at all, and the significant difference ($p < 0.001$) was related to larger mean RTs for gray-level pictures (the ranking was based on the RTs for the line drawings). For the 60 slowest-named items as line drawings

[3] It should be mentioned that the results of the RT analyses for the main effect of surface details were almost identical when conducted on the whole set of items (ie considering all names given, not only the most common name, without rejecting trials above and below 2 SDs of the mean). In both subject and item analyses, there were large effects of surface details, due to faster responses to colorized pictures than both to gray-level pictures and to line drawings. With this whole set of items, the interaction between surface details and categories due to larger effects of color with fruits/vegetables was significant in the item analysis but not in the subject analysis.

(all > 972 ms), there were significant differences between the three sets ($F_{2,118} = 90$, $p < 0.001$), with a large advantage provided by color over both line drawings and gray-level items ($p < 0.001$), but also a clear reduction of RTs for gray-level pictures compared to line drawings ($p < 0.001$).

In sum, texture speeded up object recognition only for objects that were named slowly in the original line drawings of S&V, but color played a role even when shape alone was very diagnostic and allowed subjects to name line drawings quite fast.

3.2 *Familiarity agreement*

The mean levels of familiarity were roughly equivalent between the different conditions [see appendix 2 (available online at http://www.perceptionweb.com/misc/p5117/) and table 3], and there were no significant differences among the three conditions (Kruskal – Wallis one-way analysis of variance statistic: 1.65, $p = 0.43$).

Table 3. Summary statistics for the different normative data, compared to the values of the original Snodgrass and Vanderwart (S&V) study; standard deviations computed on the item means.

	Agreement scores/H values				Familiarity			
	S&V	this study			S&V	this study		
		LD	GL	CL		LD	GL	CL
M	0.558	0.438	0.378	0.324	3.29	3.59	3.52	3.44
SD	0.526	0.560	0.520	0.460	0.956	0.942	1.011	1.007
	Visual complexity				**Image agreement**			
	S&V	this study			S&V	this study		
		LD	GL	CL		LD	GL	CL
M	2.96	2.76	2.88	2.70	3.69	3.73	3.76	3.74
SD	0.897	1.034	1.032	0.940	0.585	0.482	0.552	0.633

Note: Line drawings (LD), gray levels (GL), colorized (CL).

There was no significant correlation between the level of familiarity reported and the agreement scores of subjects for line drawings ($r = -0.002$), gray-level pictures ($r = -0.007$), or colorized pictures ($r = 0.007$). The familiarity rates did not correlate with naming RTs, for the three sets (all rs < 0.12). The advantage provided in naming latencies for colorized items over line drawings or gray-level pictures was not correlated with the familiarity of the items either (all correlation values below 0.07).

3.3 *Visual complexity*

The mean of the visual complexity measures were also almost identical across the three sets of stimuli [appendix 3 (available online at http://www.perceptionweb.com/misc/p5117/) and table 3], with no significant differences (Kruskal – Wallis one-way analysis of variance statistic: 2.29, $p = 0.31$). Again, there was no significant correlation between the level of complexity and the naming RTs for line drawings ($r = 0.16$, $p = 0.035$), gray-level pictures ($r = -0.18$, $p = 0.017$), and colorized pictures ($r = 0.16$, $p = 0.04$). The advantage provided by color information over line drawings in RTs was not correlated with the complexity of the shapes either ($r = -0.04$, $p = 0.059$).

3.4 *Imagery*

The mean of the imagery measures are reported in appendix 4, available online at http://www.perceptionweb.com/misc/p5117/ (see also table 3). There were no significant differences among conditions (Kruskal–Wallis one-way analysis of variance statistic: 2.99, $p = 0.22$). There was no significant correlation between the imagery rates and the naming RTs for any of the three sets (all ps > 0.2). Since it can be hypothesized that participants' mental images of an object include surface information, at least for objects with a diagnostic color, we also tested the imagery rates by taking into account the various categories. An analysis of variance by items with surface details and category as factors showed a main effect of category ($F_{3,236} = 11.47$, $p < 0.0001$). This effect was qualified by a highly significant interaction between surface details and category ($F_{6,472} = 12.92$, $p < 0.0001$). This was due to larger image-agreement scores obtained for animals, fruits/vegetables, and diagnostic color man-made objects when they were presented in gray-levels and colorized versions versus line drawings (all ps < 0.001), with no differences between colorized and gray-level pictures (see figure 4); but for man-made objects without diagnostic colors, the opposite effect was found (larger agreement scores for line drawings compared to gray-level and color items: ps < 0.001).

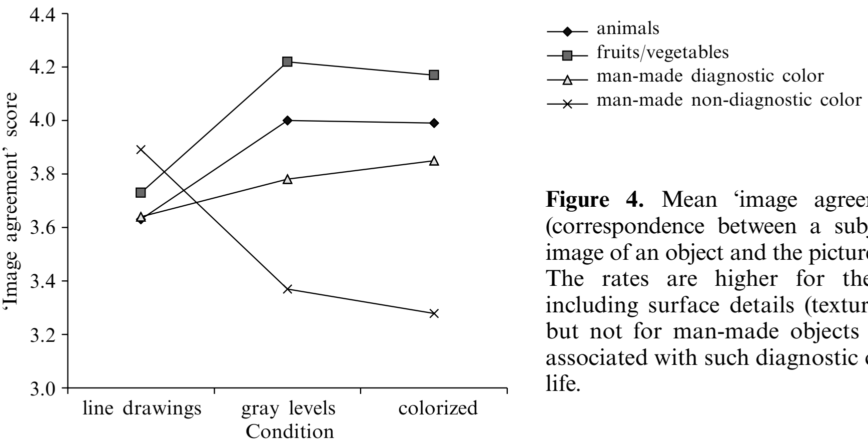

Figure 4. Mean 'image agreement' scores (correspondence between a subject's mental image of an object and the pictures presented). The rates are higher for the conditions including surface details (texture and color) but not for man-made objects that are not associated with such diagnostic colors in real life.

4 Discussion

As stated in section 1, the objectives of the present study were twofold. First, we assessed the importance of surface detail, ie color, but also texture, on the recognition of a large set of common objects in normal viewing conditions. Second, we aimed to provide a new set of 2-D pictorial objects with these surface details and with their normative data, suitable for a wide range of experimental and clinical studies.

The starting point of this project was triggered by the observation that even normal subjects may have difficulties recognizing some original items of the S&V object set (for instance, 'cloud' or 'potato'), in good viewing conditions. As a consequence, the occurrence of object-recognition deficits for instance (such as found in some brain-damaged patients with acquired visual agnosia) might be biased by difficulties in object recognition for normal subjects, related to the quality of the drawings in the original set. Hopefully, as indicated by the increase in name agreement scores for the pictures with surface-detail information, these sets will provide a better control for assessing normal and pathological performances in object recognition.

4.1 *The respective role of texture and color in basic-level 'everyday' object recognition*

The results reported in the naming task show that even in normal 'everyday' circumstances, color information improves agreement by subjects and speeds up their object-recognition processes. One unresolved question in the literature of object recognition, even for those advocating a shape + surface model of object recognition, is whether surface details other than color, such as texture alone, influence the object-recognition processes (Tanaka et al 2001). Our study suggests that texture without color has a relatively small influence on the speed of object recognition, at least in normal viewing circumstances, and when objects have to be recognized at the basic level. However, there was an advantage provided by the addition of texture alone in agreement scores for all items combined together (figure 2). The small advantages provided by the addition of texture alone were found for items that were named slowly as line drawings. In fact, for objects that are named quite fast as line drawings, the addition of texture information was found to slow down the recognition process. Effects of texture alone were found neither for pictures of fruits and vegetables, nor significantly for animals (figure 3), for which texture information may be potentially more important in real-life recognition. Yet, it may well be that in more difficult conditions of presentations, or with different tasks than object naming (such as verification tasks at different levels of categorization), the effects of texture for some categories, such as animals, would be larger. A significant advantage of surface detail without color has been found previously only by Price and Humphreys (1989) in naming and superordinate classification tasks. However, this advantage was not found for a subordinate classification task, whereas the advantage provided by color information was consistent across the three tasks in their study. Furthermore, these authors compared line drawings to black-and-white photographs, whereas the line drawings used here were compared to the very same shapes with texture filled in. Our study thus provides a better control for the role of texture alone in object naming, and suggests a limited role of this information in basic-level object recognition, at least when the edges are readily visible. In fact, we even observed a slowing down of naming RTs for the fastest-named objects as line drawings (see section 3.1.3). This would suggest that the addition of texture has an inhibitory effect on the speed of object recognition when edges are clearly visible and the objects are easily recognized. In other words, for some objects, when the edges have been already defined such as in line drawings, the addition of gray-level texture may reduce the local contrasts and make the definition of the edges harder, requiring additional segmentation processes to take place (figure 1). The addition of color information, on the other hand, will counterbalance this effect by maximizing the differences between surfaces on opposite sides of edges.

In sum, the present data cannot be unequivocally used to exclude any role of texture, without color, in basic-level object recognition, for several reasons. First, the observations made in this study suggest that texture had small effects in agreement scores, and possibly two opposite effects in naming RTs: a slowing down of the object segmentation processes for line drawings that were named particularly fast, and a speeding up of the access to the correct object representation for objects that were not readily recognized with edges only. Second, in real life, objects never appear with all their edges as clearly defined as in line drawings, and texture is undoubtedly helpful in the definition of the object shape for basic-level recognition (Regan 2000). Finally, because there was no set of objects that contained color only (line drawings + color), one cannot exclude that the large advantages provided by the colorized set (see below) may have been due to an interaction between color and texture. This possibility could be investigated in future studies.

The advantage provided by the addition of color was found for all S&V items combined, on both agreement scores, and on mean response times by subjects. Although previous researchers have reported an influence of color on RTs in object-naming tasks (eg Brodie et al 1991; Davidoff and Ostergaard 1988; Price and Humphreys 1989), to our knowledge no other study has previously shown so clearly that the addition of color alone facilitates basic-level object recognition. Indeed, we found large effects of color alone on both accuracy (eg agreement scores) and speed of correct naming, and for a particularly large sample of common objects. In addition, the effects of color were observed for all main categories of objects, not only objects with similar shapes and diagnostic colors such as fruits. Even man-made objects without a particular diagnostic color were named faster when color was present (figure 3). Finally, the fact that even highly familiar objects, and/or objects that were named very quickly and for which subjects had a high level of agreement about their correct label, benefited from the addition of color information clearly supports a role for color in normal basic-level object recognition. As one would expect, however, on the basis of previous observations (Price and Humphreys 1989; Wurm et al 1993), color appears to be more helpful for structurally similar objects (with high diagnosticity values) such as fruits and vegetables than for structurally dissimilar objects such as man-made artifacts (figure 3).

There are three stages of processing at which color information may influence object recognition (Tanaka et al 2001). First, it has been clearly shown that color is a useful cue for segmenting visual inputs in a scene, and organizing them into 3-D objects ('segmentation' process, eg Cavanagh 1987; Troscianko and Harris 1988; see Regan 2000). Second, as discussed in section 1, color may help recognition of objects by being a constituent part of the object representation (at least for objects that have a diagnostic color). This is the point that is debated between edge-based theories of object recognition and 'surface + edge-based' accounts. Third, color may also be helpful at a late semantic stage of processing objects (visual or verbal color knowledge, see Davidoff 1991; Luzzatti and Davidoff 1994).

According to edge-based theories of object recognition, color would be helpful, either at segmentation or semantic stages, only in very specific cases such as 'mass nouns' (ie objects without a specific shape, such as water, sand ...; hence the effects of diagnostic color on recognition of scenes—see Oliva and Schyns 2000), rare objects that necessitate texture information for complete representation (such as hairbrushes), objects that share the same volumetric shape (eg leopard–panther), and degraded or occluded objects (Biederman and Ju 1988).

At first glance, the influence of color on low-level visual processes such as segmentation would have been limited in our study because line-drawing objects were already completely segmented from the background. Compared to gray-level objects, color may have helped further in segregating the parts (ie when two adjacent parts have different colors, for instance) but this role was certainly limited. A point that also reinforces the view that the main advantage of color was provided at a later stage than object segmentation is that there was no correlation between the advantage provided by color (in naming latencies) and the visual complexity of the drawings. Yet, it could be argued that a large part of the effect of color observed on object naming here may be related to a role of object parts segregation, since even objects without any diagnostic color in real life benefited from the addition of color information (figure 3). However, if this advantage of colorized pictures for non-diagnostic man-made objects may indeed indicate an influence of color at lower visual stages (common for diagnostic and non-diagnostic color objects), it could also be related to an influence at the stage of object representation: even man-made objects without a specific diagnostic color in real life are usually presented in a limited number of colors, or present a dominant (or set of dominant) color(s) (see list in appendix 5, available online at http://www.perceptionweb.com/misc/p5117/). If a given shape is more frequently associated with a subset of colors than others, these colors may help disambiguate the object representation from competitors, and presenting the object shape with a congruent color might facilitate the recognition of the given object.

An argument against the view that color may be helpful only at a very late—semantic or lexical—stage of processing (Biederman and Ju 1988; Davidoff 1991) is that here, contrary to what was found by Price and Humphreys (1989), color significantly reduced correct naming latencies even for the objects named quickest, as line drawings. Another interesting observation is that the advantage of color—as measured in the reduction of naming latencies compared to gray-level pictures—was unrelated to the familiarity of the objects: even highly familiar shapes are recognized better and faster when color information is present.

By finding large effects of color on objects with distinctive shapes (no mass nouns), that had to be named at the basic level, and were not occluded, the present study thus rather supports a 'shape + surface', or at the very least a 'shape + color' model of object recognition according to which color plays a supporting role at the level of object representation (Tanaka et al 2001). The observation that image agreement scores, reflecting the compatibility between a subject's representation of an object (imagined before) and the picture presented in the set, were higher for objects presented with surface details for the categories animals, fruits/vegetables, and man-made objects with a diagnostic color (figure 4), also supports this view. This indeed suggests that subjects generated an object representation, evoked by the object name, which contained surface information and (most of the times) matched (for the upper categories) or did not match (for objects without a diagnostic color) this representation. This hypothesis could be tested more directly in the future by presenting this task to a group of subjects with all surface detail conditions randomized, including a condition with incorrect colors (eg a blue banana ...), that should lead to particularly low image agreement scores.

In the naming task, it is yet unclear how man-made objects that are not associated with a diagnostic color in real life benefited almost as much from the addition of color information as objects that are usually associated with diagnostic colors, but there are several possibilities that should be explored in future studies. For instance, color diagnosticity may be an additional critical factor for recognition only in interaction with shape similarity. If the whole shape (or shape elements) is (are) not shared by competitors, then color may not be more useful then when it is not diagnostic of the object. Thus, the effect of color may well depend on the context of recognition (the competitors). Further, the measures of color diagnosticity used here may not be as relevant as other measures of color diagnosticity. Some man-made objects have high diagnosticity scores because they are associated with a single color in real life, yet this color is shared by many objects in the category (body parts, for instance), making the color effectively non-diagnostic. By using photographs, color diagnosticity could also be measured by computing the overlap of the color space values for different instances of a basic-level object (see Oliva and Schyns 2000, for color diagnosticity on scene recognition), which might lead to different results.

4.2 *The usefulness of the new picture sets*

An important contribution of this study is the provision of two new sets of objects, which should be helpful for a number of studies involving object recognition in normal and clinical populations.

Despite the differences in procedure and the different populations tested, it is remarkable that all the mean and standard deviation values (see table 3) reported in this study, for the different norms, are fairly similar to the original ones reported by Snodgrass and Vanderwart (1980). The values for the familiarity of the line drawings are slightly higher in our study (3.59 versus 3.29), but similar to what was found more recently in a study with another set of images in a French-speaking population (3.43; Chainay et al 1998). This comparison, as well as comparisons with other normative data collected on the S&V databank of objects in other languages (Alario and Ferrand 1999; Barry et al 1997; Cuetos et al 1999; Sanfeliu and Fernandez 1996), show that the measures taken in the present study are reliable. There is also an important point to make, for the effects reported here, about the differences between the image sets in agreement scores: they could not be attributed to lower agreement scores for the line drawings used in our study compared to the original study, and thus to an artificial improvement by the addition of texture and color information. In fact, the naming agreement scores were even slightly better for the same images (line drawings) in our study, and texture and color further improved these scores (table 3). Again, these summary statistics illustrate where the effects of surface details take place: they clearly increase image agreement.

The naming times for the S&V pictures have been recently collected in a number of studies, and the global mean latency reported in our study for the line drawings (882 ms) was somewhat slower than the RTs obtained for Spanish subjects (829 ms—Cuetos et al 1999), Welsh subjects (748 ms—Barry et al 1997), English subjects (794 ms—Ellis and Morrison 1998), and American subjects (791 ms—Snodgrass and Yuditsky 1996). To our knowledge, the naming times for the S&V objects in French have not been reported before. It should also be noted that these mean RT values were obtained for different subsets of the 260 items, and after different measures of correction for long RTs in the different studies. For instance, Cuetos et al (1999) used only 140 items that had only a single-word name in Spanish and name agreement over 84%.

We believe that a large number of object-recognition studies could benefit from using the new set of pictures reported here. In particular, when objects have to be discriminated within a given category (subordinate-level categorization), they roughly share the same shape (by definition of the basic-level category) and have to be discriminated on other cues, such as texture and color. More importantly, at the individual level, objects are often discriminated on the basis of their diagnostic color (think of picking the right toothbrush in the bathroom if you live in a large family!). Color and texture cues are also generally more resistant than shape to changes in viewpoint, partial occlusion—which is actually very common, or degradation (Tanaka and Presnell 1999; Wurm et al 1993) which also changes in viewpoint.[4]

More generally, the new sets of pictures can be used to test the role of surface detail, and especially color, in object perception and recognition under different viewing circumstances and tasks. For instance, significant advantages of surface and color information in object-naming tasks have been found in a certain number of studies similar to our study (Brodie et al 1991; Chainay and Rosenthal 1996; Price and Humphreys 1989; Tanaka and Presnell 1999), but in some studies such effects in object-recognition tasks without naming have not been found (eg verification or semantic classification tasks—see Brodie et al 1991; Davidoff and Ostergaard 1988). Only a few items were used in these studies. The present set of stimuli would allow a much more systematic comparison of the role of surface detail on various object-recognition tasks such as naming, categorization, picture verification, and matching. The original S&V pictures have also been used in object-rotation studies (eg De Caro and Reeves 2000), but, again, recent evidence indicates that the strategies used to recognize rotated objects can be completely modified by the presence or absence of multiple surface cues (Nicholson and Humphrey 2001).

Our set of pictures could also be useful in a wide range of clinical studies. There are several reports of the role of color on object recognition in pathological aging (eg Chainay and Rosenthal 1996; Montanes et al 1995) and neuropsychological deficits (Chainay and Humphreys 2001; Mapelli and Behrmann 1997). For instance, visual agnosic patients generally recognize real objects better than line drawings (Farah 1990),

[4] Perhaps ironically for edge-based structural description theories which also favor the extraction of object-centered, viewpoint-independent representations (eg Biederman 1987), trends for viewpoint-independent recognition performances in object recognition are actually more likely to be found when a diagnostic color or other surface cues can be used to recognize the correct object (Hayward and Williams 2000; Nicholson and Humphrey 2001).

and this effect has been related to a role of shading cues in guiding the segmentation of objects into parts (Chainay and Humphreys 2001) and of color knowledge (Mapelli and Behrmann 1997), but also of depth information (Chainay and Humphreys 2001), which is unavailable on 2-D pictorial stimuli as used here. The comparison of real objects to line drawings, gray-level objects, and colorized objects would certainly allow better characterization of the different cues that can be helpful in recognizing objects under normal and pathological conditions.

5 Conclusions

We provide refined, high-quality, textured and colored versions of Snodgrass and Vanderwart's 260 black-and-white line drawings, with normative data on variables relevant to visual, amnesic, and cognitive processing. Comparisons of the three sets clearly show that the addition of texture and mainly color significantly improves naming agreement and naming latencies. Several observations suggest a role of color at the level of the object representation, and thus support the surface + shape model of object recognition (Tanaka et al 2001). The stimuli and the corresponding normative data provide valuable materials for a wide range of experimental and clinical studies.

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References

Alario F X, Ferrand L, 1999 "A set of 400 pictures standardized for French: Norms for name agreement, image agreement, familiarity, visual complexity, image variability, and age of acquisition" *Behavior Research Methods, Instruments & Computers* **31** 531–552

Ardila A, Ostrosky-Solis F, Rosselli M, Gomez C, 2000 "Age-related cognitive decline during normal aging: The complex effect of education" *Archives of Clinical Neuropsychology* **15** 495–513

Barry C, Morrison C M, Ellis A W, 1997 "Naming the Snodgrass and Vanderwart pictures: Effects of age of acquisition, frequency and name agreement" *Quarterly Journal of Experimental Psychology A* **50** 560–585

Berndt R S, Burton M W, Haendiges A N, Mitchum C C, 2002 "Production of nouns and verbs in aphasia: Effects of elicitation context" *Aphasiology* **16** 83–106

Biederman I, 1987 "Recognition-by-components: A theory of human image understanding" *Psychological Review* **94** 115–147

Biederman I, Ju G, 1988 "Surface versus edge-based determinants of visual recognition" *Cognitive Psychology* **20** 38–64

Brodie E E, Wallace A M, Sharrat B, 1991 "Effect of surface characteristics and style of production on naming and verification of pictorial stimuli" *American Journal of Psychology* **104** 517–545

Brooks P J, MacWhinney B, 2000 "Phonological priming in children's picture naming" *Journal of Child Language* **27** 335–366

Bruner J, 1957 *Contemporary Approaches to Cognition* (Cambridge, MA: Harvard University Press)

Cavanagh P, 1987 "Reconstructing the third dimension: interaction between color, texture, motion, binocular disparity and shape" *Computer Vision Graphics and Image Processing* **37** 171–195

Chainay H, Humphreys G W, 2001 "The real-object advantage in agnosia: Evidence for a role of surface and depth information in object recognition" *Cognitive Neuropsychology* **18** 175–191

Chainay H, Rosenthal V, 1996 "Naming and picture recognition in probable Alzheimer's disease: Effects of color, generic category, familiarity, visual complexity and shape familiarity" *Brain and Cognition* **30** 403–405

Chainay H, Rosenthal V, Goldblum M C, 1998 "A standardized set of 315 color and black-and-white pictures for use in semantic memory and naming experiments" *Revue de Neuropsychologie* **8** 179–239

Cuetos F, Ellis A W, Alvarez B, 1999 "Naming times for the Snodgrass and Vanderwart pictures in Spanish" *Behavior Research Methods, Instruments & Computers* **31** 650–658

Damian M F, 2000 "Semantic negative priming in picture categorization and naming" *Cognition* **76** B45–B55

Davidoff J, 1991 *Cognition through Color* (Cambridge, MA: MIT Press)

Davidoff J B, Ostergaard A L, 1988 "The role of colour in categorical judgement" *Quarterly Journal of Experimental Psychology A* **40** 533 – 544

De Caro S A, Reeves A, 2000 "Rotating objects to determine orientation, not identity: Evidence from a backward-masking/dual-task procedure" *Perception & Psychophysics* **62** 1356 – 1366

Dell'Acqua R, Job R, Grainger J, 2001 "Is global shape sufficient for automatic object identification?" *Visual Cognition* **8** 801 – 821

Dell'Acqua R, Lotto L, Job R, 2000 "Naming times and standardized norms for the Italian PD/DPSS set of 266 pictures: direct comparisons with American, English, French, and Spanish published databases" *Behavior Research Methods, Instruments & Computers* **32** 588 – 615

Ellis A W, Morrison C M, 1998 "Real age of acquisition effects in lexical and episodic memory tasks" *Memory and Cognition* **7** 214 – 223

Farah M J, 1990 *Visual Agnosia: Disorders of Object Recognition and What They Tell Us about Normal Vision* (Cambridge, MA: MIT Press)

Gibson E, 1969 *Principles of Perceptual Learning and Development* (New York: Appleton-Century-Crofts)

Graham K S, Patterson K, Pratt K H, Hodges J R, 2001 "Can repeated exposure to 'forgotten' vocabulary help alleviate word-finding difficulties in semantic dementia? An illustrative case study" *Neuropsychological Rehabilitation* **11** 429 – 454

Grossberg S, Mingolla E, 1985 "Neural dynamics and perceptual grouping: textures, boundaries and emergent segmentations" *Perception & Psychophysics* **38** 137 – 144

Harmony T, Fernandez T, Fernandez-Bouzas A, Silva-Pereyra J, Bosch J, Diaz-Comas L, Galan L, 2001 "EEG changes during word and figure categorization" *Clinical Neurophysiology* **112** 1486 – 1498

Hayward W G, Williams P, 2000 "Viewpoint dependence and object discriminability" *Psychological Science* **11** 7 – 12

Kohler S, Moscovitch M, Melo B, 2001 "Episodic memory for object location versus episodic memory for object identity: Do they rely on distinct encoding processes?" *Memory & Cognition* **29** 948 – 959

Luzzatti C, Davidoff J, 1994 "Impaired retrieval of object-color knowledge with preserved color naming" *Neuropsychologia* **32** 933 – 950

Mapelli D, Behrmann M, 1997 "The role of color in object recognition: Evidence from visual agnosia" *Neurocase* **3** 237 – 247

Marr D, 1982 *Vision* (New York: W H Freeman)

Marr D, Nishihara H K, 1978 "Representation and recognition of the spatial organization of three-dimensional shapes" *Proceedings of the Royal Society of London, Series B* **200** 269 – 294

Montanes P, Goldblum M C, Boller F, 1995 "Naming color and black-and-white pictures from living and nonliving things in Alzheimer's disease" *Journal of the Experimental Neuropsychological Society* **1** 39 – 48

Nicholson K G, Humphrey G K, 2001 "Surface cues reduce the latency to name rotated images of objects" *Perception* **30** 1057 – 1081

Oliva A, Schyns P G, 2000 "Diagnostic colors mediate scene recognition" *Cognitive Psychology* **41** 176 – 210

Op de Beeck H, Béatse E, Wagemans J, Sunaert S, Van Hecke P, 2000 "The representation of shape in the context of visual object categorization tasks" *Neuroimage* **12** 28 – 40

Ostergaard A L, Davidoff J, 1985 "Some effects of color on naming and recognition of objects" *Journal of Experimental Psychology: Learning, Memory, and Cognition* **11** 579 – 587

Ousset P J, Viallard G, Puel M, Celsis P, Démonet J F, Cardebat D, 2002 "Lexical therapy and episodic word learning in dementia of the Alzheimer type" *Brain and Language* **80** 14 – 20

Pashler H, Harris C R, 2001 "Spontaneous allocation of visual attention: Dominant role of uniqueness" *Psychonomic Bulletin & Review B* **8** 747 – 752

Pechmann T, Zerbst D, 2002 "The activation of word class information during speech production" *Journal of Experimental Psychology: Learning, Memory, and Cognition* **28** 233 – 243

Pind J, Jónsdóttir H, Gissurardóttir H, Jónsson F, 2000 "Icelandic norms for the Snodgrass and Vanderwart (1980) pictures: Name and image agreement, familiarity, and age of acquisition" *Scandinavian Journal of Psychology* **41** 41 – 48

Price C J, Humphreys G W, 1989 "The effects of surface detail on object categorization and naming" *Quarterly Journal of Experimental Psychology A* **41** 797 – 828

Regan D, 2000 *Human Perception of Objects: Early Visual Processing of Spatial Form Defined by Luminance, Color, Texture, Motion and Binocular Disparity* (Sunderland, MA: Sinauer Associates)

Rossion B, Pourtois G, 2001 "Revisiting Snodgrass and Vanderwart's object database: Color and texture improve object recognition" *Journal of Vision* **1** 413a (abstract)
Sanfeliu M C, Fernandez A, 1996 "A set of 254 Snodgrass – Vanderwart pictures standardized for Spanish: Norms for name agreement, image agreement, familiarity, and visual complexity" *Behavior Research Methods, Instruments & Computers* **28** 537 – 555
Sanocki T, Bowyer K W, Heath M D, Sarkar S, 1998 "Are edges sufficient for object recognition?" *Journal of Experimental Psychology: Human Perception and Performance* **24** 340 – 349
Snodgrass J G, Vanderwart M, 1980 "A standardized set of 260 pictures: norms for name agreement, image agreement, familiarity, and visual complexity" *Journal of Experimental Psychology: Learning, Memory, and Cognition* **6** 174 – 215
Snodgrass J G, Yuditsky T, 1996 "Naming times for the Snodgrass and Vanderwart pictures" *Behavior Research Methods, Instruments & Computers* **28** 516 – 536
Stark C E L, Squire L R, 2000 "Functional magnetic resonance imaging (fMRI) activity in the hippocampal region during recognition memory" *Journal of Neuroscience* **20** 7776 – 7781
Tanaka J W, Presnell L M, 1999 "Color diagnosticity in object recognition" *Perception & Psychophysics* **61** 1140 – 1153
Tanaka J W, Weiskopf D, Williams P, 2001 "The role of color in high level vision" *Trends in Cognitive Sciences* **5** 211 – 215
Tarr M J, Bülthoff H H, 1998 "Image based recognition in man, monkey and machine" *Cognition* **67** 1 – 20
Tarr M J, Williams P, Hayward W G, Gauthier I, 1998 "Three-dimensional object recognition is viewpoint dependent" *Nature Neuroscience* **1** 275 – 277
Thomas G V, Nye R, Rowley M, Robinson E J, 2001 "What is a picture? Children's conceptions of pictures" *British Journal of Developmental Psychology* **19** 475 – 491
Troscianko T, Harris J, 1988 "Phase discrimination in compound chromatic gratings" *Vision Research* **28** 1041 – 1049
Van Petten C, Senkfor A J, Newberg W M, 2000 "Memory for drawings in locations: Spatial source memory and event-related potentials" *Psychophysiology* **37** 551 – 564
Ward J, Parkin A J, 2000 "Pathological false recognition and source memory deficits following frontal lobe damage" *Neurocase* **6** 333 – 344
Williams P, Tanaka J W, 2000 "Color effects on the recognition of distinctively shaped objects", unpublished manuscript, Oberlin College, Oberlin, OH 44074, USA
Wurm L, Legge G E, Isenberg L M, Luebker A, 1993 "Color improves object recognition in normal and low vision" *Journal of Experimental Psychology: Human Perception and Performance* **19** 899 – 911

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