# Does banana spontaneously activate yellow color? Color-related concepts help with color discrimination

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**Abstract**

Color is a critical part of objects representation as well as critical cue for recognizing objects. However, it is less clear how people represent color in memory. The present study aimed at investigating this issue. We designed a procedure based on short-term sensory memory load procedure mixed with a color-priming paradigm. Participants learned three visual stimuli (either non-words – lexical load condition - or visual-shapes – visual-shape load condition). Then, they performed a color discrimination task on colored patch (e.g., a yellow patch). Each target was preceded by a color-related concept word either congruent (e.g., word "banana") or not (e.g., word "lettuce"). Finally, they performed a recognition task either on non-words or on visual-shapes depending on the memory load condition). We showed that color-priming effect was selectively disrupted in visual-shape load condition. We interpreted this finding as an evidence that automatic modal simulations occur during access to the meaning of color-related concept.

**Keywords:** Color knowledge, perceptual simulation, priming effect, visual memory

## Introduction

Color knowledge about object is an important part of conceptual representation. Indeed, color is often a critical cue for recognizing object (Tanaka & Presnell, 1999) or natural scene (Oliva & Schyns, 2000) in everyday life. Hansen, Olkkonen, Walter, and Gegenfurtner (2006) suggested that research about color should investigate how people represent color rather than how people perceive color because color of an environment is never stable over the time (i.e., dependent of the objects' illumination) and, as a consequence, dependent from color knowledge. The question is how do people represent color knowledge?

First, color knowledge could be considered as stored in an amodal format within conceptual representation of an object. In that view, meaning of an object is distributed across semantic features (see Masson, 1995) and relationships between concepts are explained in term of overlapping between semantic features. As soon as two concepts share the same semantic color feature, one can prime the other. For instance, hearing the word "lips" could facilitate the detection of the picture of a strawberry (Huettig & Altmann, 2011). However, several studies suggest that access to color knowledge depend on the nature of the stimuli (i.e., lexical vs. visual, see Nijboer, Zandvoort & Haan, 2006). Indeed, because the word "banana" and "yellow" co-occurs frequently in everyday language, color knowledge could also be stored in a lexical format: a color label (see Landauer & Dumais, 1997). In that case, as soon as two concepts share the same color label, one can prime the other. For instance, hearing the word "pea" could facilitate the detection of the picture of a green blouse (see Huettig & Altamann, 2011) because both objects share the label "green". In the same vein, Roberson and Davidoff (2000) have showed a loss of the categorical perception (i.e., better discrimination across color categories than within the same color category) when participants had to simultaneous discriminate between colors and maintain words in memory. This effect was not observed when they had to follow a curved line with the eyes. Accordingly, it seems that lexical access interferes with categorical perception, while visual interference does not. This result suggests the implication of lexical units during access to color knowledge. Moreover Nijboer and collaborators (2006) demonstrated that color-priming effect (from object-word or object-picture to colored-patch) is dependent of the nature of the prime (either picture or word, see also Heurley, et al., 2013). This result suggests the existence of both a semantic-based and lexical-based representation of color. These two formats of color knowledge are not necessary incompatible and authors suggested a time-based access distinction for accounting existence of both level of representation (Heurley et al., 2013).

Alternatively, theories of embodied or grounded cognition (see Barsalou, 2008) assume that access to a representation is linked with perceptual sensory simulations. In other words, performing a conceptual task like verifying that a "banana" is "yellow" is associated with the automatic simulation of a former visual experience associated with the banana (Pecher, Zeelenberg, & Barsalou, 2003, 2004; Van Dantzig, Pecher, Zeelenberg, & Barsalou, 2008; Vermeulen, Chang, Corneille, Pleyers, & Mermillod, 2013; Vermeulen, Corneille, & Niedenthal, 2008). Thus, access to the meaning of concept involves automatic perceptual simulation in several sensory modalities and, as a consequence, influences processing of stimuli presented in the same modality than the simulated one (see Brunel, Goldstone, Vallet, Riou, & Versace, 2013; Brunel, Labeye, Lesourd, & Versace, 2009; Brunel, Lesourd, Labeye, & Versace, 2010; Vallet, Brunel, & Versace, 2010; for a review see Versace, Labeye, Badard, & Rose, 2009). In that case, color knowledge could be defined as perceptual or modal rather than semantic or lexical. Indeed, neuroimagery studies showed that either perceiving or conceiving color involves common neural substrates (Simmons et al., 2007). Moreover, Richter and Zwaan (2009) showed that processing color words (e.g., word "red") involves perceptual simulation of the color. They showed that participants were faster at discriminating between targets colored-square displayed in the same category color (e.g., light red vs. dark red) when the prime color word and the targets colored squares match on their color rather than mismatch. According to the authors, their results ruled out an explanation based on a lexical competition since the prime word and the target squares shared the same color label. Finally, Yee, Ahmed and Thompson-Schill (2012) found a contextual-based color priming effect using a semantic priming procedure. Indeed they found that color-priming effect is observed only when color was sensitized before the priming procedure. According to the authors, this result seemed to indicate that color knowledge is context dependent rather than stable over the time that is consistent with an embodied approach but not with a semantic approach (see also Connell, 2007; Connell & Lynott, 2009 for a similar conclusion)

Given existence of empirical evidence for both approaches (embodied vs. semantic or lexical), this article aims at addressing the issue about the representational format of color knowledge in memory. In the present study, we designed a single paradigm in order to test simultaneously each assumption regarding the nature of color knowledge (i.e., perceptual/modal vs. lexical/amodal). To do so, we adapted the procedure of Vermeulen and co-workers (2008, see also Vermeulen, Chang, Mermillod, Pleyers & Corneille, in press, Experiment 2). In their experiment, they combined a short-term memory task (i.e., memory load) with a property verification task. Consequently, they manipulated both the nature of the memory load (i.e., visual or auditory) and the nature of the property (i.e., visual or auditory) during the property verification task. First, participants had to learn items visually or auditory displayed. Then they had to perform a property verification task like verifying that a banana could be yellow. After that, they had to recognize the previously learnt items from a new list displayed in the same modality. The main results of their study is that participants were significantly slower at verifying visual properties preceded by a visual-shape load than an auditory load and conversely for auditory properties. Authors concluded that sensory memory and conceptual memory share the same modal properties. In our procedure, we changed the nature of the items in the short-term memory task and replaced the property verification task by a color priming procedure (Heurley, et al., 2013). As a consequence, participants firstly maintained three stimuli in visual memory either meaningless lexical stimuli (i.e., non-words) or meaningless visual-shapes (i.e., Gaussian blobs) before performing a color discrimination task on colored patches. Each target colored patch (e.g., a yellow patch) was preceded by a word prime that could represent a color-related concept (e.g., the word "banana") or not (e.g., the word "lettuce"). Heurley and collaborators (2013, see also Nijboer et al., 2006) found that participant were faster at discriminating the color of the patch when prime was congruent rather than incongruent, attesting a color-priming effect from color-related concept primes to colored targets patches. Finally, participants completed a recognition task on the previously learnt elements.

Our procedure should let us to directly test different assumptions about the format of the color knowledge. First, if accessing to color knowledge from a color-related concept involves semantic amodal knowledge about color, we should find a significant interaction between Prime Type (yellow or green color related concept) and Color Target (yellow or green patches) irrespective the nature of the memory load. A given word activates its conceptual semantic representation in memory (see, Masson, 1995) which include diagnostic feature about the concept. Since this representation is activated at a semantic level, it should not interact with any of the item of the load conditions because each item for these conditions is meaningless. This result would be a direct replication of Heurley and co-workers (2013) Experiments. Then, if accessing color from a color-related concept involves lexical knowledge (such as verbal label), we should find an interaction between Prime Type and Color Target and the Nature of the Memory Load. In that case, the word prime activates the color representation at a lexical level and should interact specifically with the items of the lexical load condition. As a consequence, we might predict a diminution (or a lost) of color-priming effect consecutive to the lexical load condition while the color-priming effect should be observed

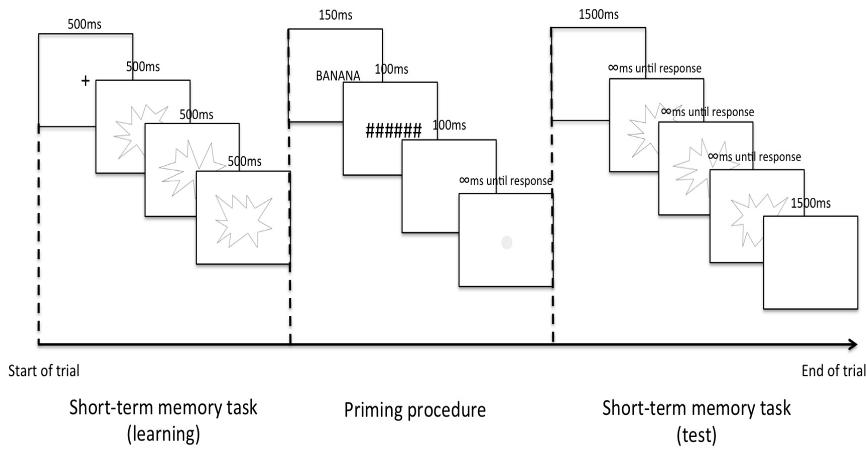


**Figure 1:** Trial overview for both training and test phase in the visual-shape load condition. Note: The colored patch is represented into grey scale but was displayed either in yellow or green during the experiment.

with the visual-shape load condition. Finally, if accessing color from a color-related concept involves visual simulation, we should observe the opposite pattern. In that case, processing the word automatically simulates former visual experiences associated with the concept and those simulations should interact with the items of the visual-shape load condition. As a consequence, we might predict a diminution (or a lost) of color-priming effect consecutive to the visual-shape load condition while the color-priming effect should be observed with the lexical load condition.

## Experiment

**Participant –** Twenty-Four native French speakers (student from Université Paul-Valery, Montpellier, France) were recruited and received courses credits for their participation. All have a normal or corrected to the normal vision and none of them reported having atypical color perception (Daltonism or synesthesia)

**Stimuli & Material –** We created 12 Gaussian blobs (6 for training and 6 for test) that were equilibrated in term of surface, number of angles and of peaks in both sides regarding a vertical symmetric axis. We created also 12 CVC-CVC non-words (6 for training and 6 for test) following Reinitz, Lammers, and Cochran (1992) methodology. These stimuli were used in the short-term memory task, respectively in the visual-shape load and lexical load conditions. For the priming phase, we used the same material than Heurley and co-workers (2013; see also Reilhac & Jiménez, 2006). The 16 priming words (4 for training and 12 for test) depicted either animal or vegetable typically associated with the color green (e.g., lettuce) or yellow (e.g., banana). The target stimuli were yellow (R = 255; G = 255; B = 0) or green patches (R = 34; G = 163; B = 13) according to the RGB color model. We also used a mask that was a white screen with 17 lines of 60 black stars (i.e., *).

**Procedure –** After filling out a consent form, participants were tested individually in a computer room. Each trial started with a fixation-cross lasting on the screen during 500ms followed by three successive visual stimuli (either non-words or visual-shapes depending on the memory load condition), each lasting 500ms. Participants were informed that they have to learn these stimuli in order to perform a later recognition task. Then a prime word was prompted on the screen (150ms) and was immediately replaced by a visual mask (100ms) itself replaced by a blank screen (100ms). A target colored patch followed and participants had to judge as quickly and accurately as possible its color. After 1500ms blank screen, 3 stimuli (non-words or visual-shapes) were successively displayed and participants have to judge for each stimuli if it corresponded or not to a previously learnt stimulus. We set the inter-trial interval at 1500ms (see Figure 1). Participant indicated their responses by pressing different keyboard's keys for the color discrimination task and for the recognition task. The responses keys were counterbalanced between participants.

The experiment started with a training phase (16 trials) followed by a test phase composed by 48 trials randomly presented: 24 in the visual-shape-load and 24 in lexical-load condition. Each prime was seen followed by each target patch and for each load condition. For the short-term memory task, we have controlled that the number of "same" and "different" was identical for each position during test compared to the learning and for each conditions: visual-shape-load and lexical-load.

## Results

Table 1. Mean correct RT and correct response rates for each experimental condition. Note: Priming effect was calculated by subtracting incongruent experimental conditions (e.g., "yellow" prime / green target condition) to the congruent ones (e.g., "yellow" prime / yellow target condition). A negative value indicates facilitation (i.e., a gain toward the congruent condition) whereas a positive value indicates a cost.

| | | Lexical | | | | Visual-shape | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | "Yellow" Prime | | "Green" Prime | | "Yellow" Prime | | "Green" Prime | |
| | | RT(ms) | CR | RT(ms) | CR | RT(ms) | CR | RT(ms) | CR |
| Target Color | Yellow | 493 (21) | 0.965 (.018) | 531 (26) | 0.971 (.013) | 518 (28) | 0.978 (.012) | 525 (27) | 0.942 (.021) |
| | Green | 529 (24) | 0.965 (.017) | 490 (28) | 0.976 (.013) | 517 (27) | 0.962 (.013) | 528 (29) | 0.957 (.018) |
| | Priming effect | -36 | | -42 | | 1 | | 2 | |

*Color Discrimination Task* - The mean correct response latencies and mean percentages of correct responses were calculated across subjects for each experimental condition. Latencies below 250 ms and above 1,250 ms were removed (this cut-off resulted in the exclusion of 2.95% of the data, see Brunel et al., 2009). The participants performed the test color categorization task accurately (overall correct response rate of 96.45%, see Table 1). Practice trials were removed from the analysis.

A repeated analysis of variance was performed with subjects as random variable, Nature of Memory Load (Lexical vs. Visual-shape), Prime Type (yellow-related concept vs. a green-related concept) and Target Color (Yellow vs. Green) as within-subjects variables.

Analysis revealed neither significant main effects of the Nature of Memory Load, $F(1, 23) = 1.79$, $p = .19$, $\eta^2_p = .07$, Prime Type, $F < 1$, Target Color, $F < 1$ nor interaction between Nature of Memory Load and Prime Type, $F < 1$, and between Nature of memory Load and Target Color, $F < 1$. Analysis showed a significant interaction between Prime Type and Target Color, $F(1, 23) = 7.14$, $p < .05$, $\eta^2_p = .24$. However, the Nature of Memory Load modulates this interaction. Indeed analysis revealed a significant three way interaction between Nature of the Memory Load, Prime Type and Target Color, $F(1, 23) = 7.33$, $p < .05$ , $\eta^2_p =.24$. This interaction is depicted in Figure 2.

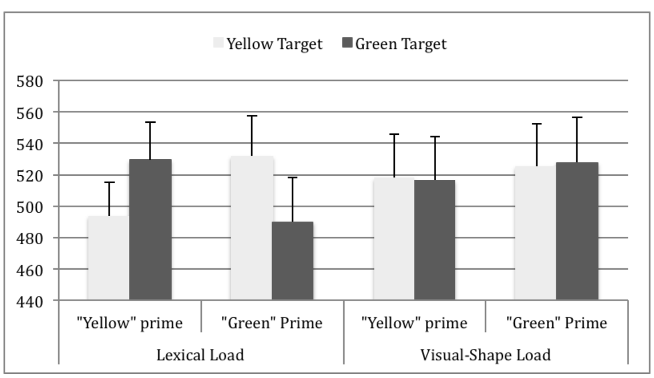


**Figure 2:** Mean correct RT for each experimental condition. Error bar represents standard error.

As can be appreciated in Figure 2, the interaction between Prime Type and Target Color was observed in the lexical load condition, but not in the visual-shape load condition. Regarding the lexical load condition, participants were significantly faster at judging the green patch preceded by a congruent prime (i.e., a green-related concept like a lettuce) than an incongruent prime (i.e., a yellow-related concept like a banana), $F(1, 23) = 7.60$, $p < .05$. The reverse was observed for the yellow patch, $F(1, 23) = 4.61$ , p < . 0.5.

Regarding the visual-shape load condition. The Prime Type did not modulate color discrimination. The difference between the primes was not significant for the yellow patch, $F < 1$, as well for the green patch, $F < 1$.

*Recognition Task* – A t-test conducted between the correct recognition rates of the different memory load conditions revealed that participants were significantly worst for the memory test in the visual-shape load condition (M = .672, SE = .021) than in lexical condition (M = .729, SE = .015), $t(23) = 3.25$ , $p < .05$.

*Correlation Analysis* - We also tested the correlation between the memory test accuracy and the priming effect size (RT congruent – RT incongruent)[1] for both condition of memory load and each participant. Indeed, Vermeulen and collaborators (2008) showed that memory performances were selectively influenced by the relation between the nature of the load (i.e., visual or auditory) and the nature of the to be verified property (i.e., visual or auditory). Accordingly, we might expect a negative correlation between the priming effect size and the memory performance in the visual-shape load condition. In other words, less the visual-shape load is efficient (attesting by a high recognition rate) the higher is the probability to observe a priming effect. Conversely, we should not observe any correlation for the lexical load condition.

[1] We collapsed congruent RTs (Yellow prime/Yellow target and Green prime/Green target) and we did the same for the incongruent RTs (Yellow prime/Green target and Green prime/Yellow target.

We found a significant negative correlation (Spearman Correlation) between the priming effect size and the memory performance for the visual-shape load condition, $r(22) = -.46$, $p < .05$, but not for lexical load condition, $r(22) = +.02$.

## Discussion

The aim of this study was to propose a procedure for disentangling between several conceptions about nature of color knowledge in memory. To do so, we combined a color-priming paradigm (Heurley, et al., 2013) with a short-term memory load procedure (Vermeulen, et al., 2008). First, participants had to learn three visual elements (either non-words or shapes). Then, they had to perform a color discrimination task where each colored-target (e.g., yellow patch) was preceded by a congruent color-related word concept (e.g., "banana") or not (e.g., "lettuce"). Finally, they performed a recognition task on either non-words or visual-shapes depending on the memory load condition. Our results seem to indicate that access to color knowledge involves perceptual simulation rather than lexical or semantic activation. Indeed, we found that color-priming effect (i.e., shorter RTs when the color of the patch was congruent with color-related concept word rather than incongruent) was incurred in the visual-shape load condition while it was observed in the lexical load condition. This should be due to a competition for same visual resources between the short-term storage of shapes in memory and the simulation of the color-related concepts (see Vermeulen, Corneille et al., 2008; Vermeulen, Chang et al., in press, for a similar conclusion). Moreover, the fact that we found a significant negative correlation between priming size effect and the accuracy in short-term memory task in the visual-shape load condition (while the same correlation was not significant in the lexical load condition) is consistent with our interpretation. Moreover, this result is in accordance with Yee and co-workers' (2012) experiment. Indeed, they found a positive correlation between Stroop interference and color-priming gain only when the Stroop task was presented before the priming procedure. This result attested that color-priming effect was modulated by the Stroop task. Taken together, these results indicate that access to color information related to object is not only contextually dependent but also sensory-based. Finally, our results bring direct evidence that access to an object concept using words involved automatic modal simulation (see also Vermeulen et al., in press). Indeed, this paper showed that words representing modal concept spontaneously involve perceptual simulations (without engaging participant in a property verification task) so that a perceptual load (in the same modality than the modal concept) selectively incurs memory for these words.

In conclusion, our study provides a strong argument in favor of the idea that access to conceptual knowledge is linked to the simulation of the sensory dimension captured within the concept (see Barsalou, 2008) so that experiencing a concept in a given modality involves perceptual simulation in the same sensory modality and in the other related sensory (Brunel, Lesourd, et al., 2010) or motor modalities (Brouillet, Heurley, Martin, & Brouillet, 2010).

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