Is a Bear White in the Woods?
Effects of Implied Perceptual Information on Stroop Color-Naming

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Abstract

Color is undeniably important to object representations, but so too is the ability of context to alter the color of an object. This study examined whether canonical knowledge about typical color or contextual knowledge about scenario-specific color plays a central role in object representation. Participants performed a modified Stroop task that asked them to name the color of a target word (typical or atypical), following presentation of a sentence that implied a (matching or mismatching) color for the target object. Context was found to affect naming of atypical ink colors (e.g., "tomato" in green) with faster responses in the match condition, and with faster naming of typical ink colors (e.g., "tomato" in red) regardless of whether context matched or mismatched. These results suggest that typical color is ordinarily dominant but that unusual contexts cause people to hold in mind both typical and scenario-specific perceptual information.

Introduction

Imagine a person sitting in a car listening to a news report. This is an everyday cognitive event and yet is fraught with many unresolved issues. Say the report is about international efforts in bear conservation: how do we represent a bear that is not actually in front of us at the time? How do we represent its appearance – with sharp teeth and typically thick, brown fur? Does our mental bear change color to white if the report mentions the North Pole? The ability to utilise and adapt conceptual knowledge is central to human cognitive life, and how we manage to do this is a key question in cognition research.

Research has shown that color is an important part of our conceptual representation of objects (Halff, Ortony & Anderson; 1976; Naor-Raz, Tarr & Kersten, 2003; Nicholson & Humphrey, 2004). Knowledge about color typicality allows us to recognize objects with highly diagnostic colors (e.g., *banana* or *fire engine*) more rapidly than objects with no particular diagnostic color (e.g., *dog* or *lamp*: Tanaka & Presnell, 1999). Indeed, our conceptual knowledge of an object's typical color is more influential in object recognition than the color actually perceived (Mapelli & Behrman, 1997; Tanaka & Presnell, 1999). For example, when participants are primed with a picture of a purple apple (i.e., displayed in an atypical color), they are faster to recognize a cherry (which shares the prime's typical color red) than a blueberry (which shares the prime's displayed color purple; Joseph & Proffitt, 1996).

However, the presence of context can easily alter conceptual considerations of an object's color. For example, when asked to compare the color *grey* to *black* and to *white*, Medin and Shoben (1988) found that people considered *grey* to be more similar to *white* in the context of hair, but more similar to *black* in the context of clouds. Similarly, Halff et al. (1976) found that people represented the color *red* differently for hair, wine, flag, brick, and blood, considering the color of a *red flag* to be more similar to a *red light* than a *red wine*.

Such context effects are not limited to simple noun-color combinations, but have also been found for larger scenarios. Research in embodied or situated cognition (see Wilson, 2002, for review) has shown that people represent implied perceptual information during sentence comprehension even though doing so does not facilitate task performance (Connell, 2005, in press; Stanfield & Zwaan, 2001; Zwaan, Stanfield & Yaxley, 2002). In the case of color, Connell (2005, in press) has shown that short-term, contextual representations of object color can affect people's ability to recognise objects. For example, participants were presented with a sentence that implied a particular color for an object (e.g., "The driving instructor told Bob to continue at the traffic lights"), followed by a picture of the object (e.g., traffic lights). Connell found that people were slower to verify that traffic lights had been mentioned when it was pictured in the color implied by the sentence (i.e., *green light*), compared to when it was pictured in an alternative color (i.e., *red light*). In the absence of any prior context, people can easily ignore the perceptual color of a stimulus when attending to shape in an object recognition task (Proverbio et al., 2004). In the presence of context, however, Connell suggested that people may find it difficult to ignore the perceptual green of a pictured traffic light when a short-term representation of *greenness* had been activated by the preceding sentence.

So what happens if our context-specific representation of an object conflicts with our canonical knowledge? Theories of embodied cognition usually describe color representation as the specialization of a perceptual simulation to include color information (Barsalou, 1999; Zwaan, 2004). However, there has been little discussion of how such specialization might take place if the object simulation is already specialized with a typical color. For example, we know that tomatoes are usually *red* but we may encounter a scenario in which they are *green*. Which representation – contextual or canonical – plays a dominant role? The "semantic Stroop" provides an interesting paradigm to investigate this question.

Semantic Stroop

While the original Stroop (1935) study showed that automatic reading of color terms interfered with people's ability to name ink color (e.g., incongruent "blue" written in red is slower than congruent "red" written in red), further research has demonstrated the influence of context on performance in Stroop tasks (see MacLeod, 1991 for a review). For example, Warren (1972) showed that people were slower to name the ink color of a target word if it had been primed by preceding context (e.g., priming with "aunt", "uncle" and "cousin" interfered with color-naming for "relatives"). However, priming can also facilitate color-naming: if the ink color of a target word is primed (even unconsciously), participants are faster to respond with the color name (Cheesman & Merikle, 1986; Kouider & Dupoux, 2004). Knowledge of property dominance within a concept also has a bearing on whether context interferes in a Stroop task. When a low-dominance property is presented (e.g., "buzz" for *bee*), people experience interference in naming ink color only when the preceding sentence had already implied that property (e.g., interference for "The child heard the bee" but not for "The child was hurt by the bee"), but high-dominance properties (e.g., "sting" for *bee*) produce interference regardless of context bias (Whitney et al., 1985).

As a variant, the semantic Stroop was first developed by Klein (1964; see also Ménard-Buteau & Cavanagh, 1984), who extended the classic Stroop paradigm to show the same interference effect occurred for object nouns with associated color typicality. For example, using target words that were semantically associated with color such as "sky" and "blood", Klein found that participants were slower to name the ink color when it was atypical for that object (e.g., incongruent "sky" written in red is slower than congruent "blood" written in red). However, recent findings suggest that such slowed naming times in the semantic Stroop task appear to be the product of a blocked list design (i.e., where each condition is presented to participants as separate stimuli lists). Naor-Raz et al. (2003) argued that blocked list designs allow participants to focus attention strategically (i.e., to ignore or defocus words in incongruent lists, but to attend sharply in congruent lists), while mixed designs with randomized single-item presentation prevent such selective strategies (for similar strategizing in emotional Stroop tasks, see Dalgleish, 1995; Holle, Neely & Heimberg, 1997). Naor-Raz et al. found that Klein's (1964) semantic Stroop effect was actually inverted when the stimuli were presented in a randomized mixed design (e.g., incongruent "banana" written in purple faster than congruent "banana" written in yellow). They concluded that presenting color-associated words activates object information (e.g., "banana" activates *yellow*) which hinders naming ink color when participants attempt to access the same name in the congruent condition.

The findings detailed above leave us with several interesting issues. We know that presenting color-associated words in their typical color causes interference in naming, at least for randomized experimental designs (Naor-Raz et al., 2003). Will this effect of canonical knowledge (e.g. tomatoes are typically *red*) still slow color-naming if a mismatching prior context is used (e.g., where tomatoes are *green*)? We also know that low-dominance properties are not activated by object mention (and hence do not cause interference in color-naming) unless the preceding context has specifically primed that property (Whitney et al., 1985). Will this context effect also mean that naming atypical ink colors (e.g., "tomato" in green) will only be affected if preceded by a matching atypical context (e.g., *green* tomatoes)? The aim of the following study is to address these questions.

The Current Study

We have seen above that color is undeniably important to object representations, but so too is the ability of context to alter its representation. This study's objective is to examine how canonical and contextual knowledge about object color interact: whether canonical knowledge about typical color or context-specific knowledge about color plays a central role. In the experiment, people are asked to perform a modified Stroop task that tests whether canonical and/or contextual color information is activated during sentence comprehension. Participants are presented with a color-associated word such as "tomato" (in either typical *red* or atypical *green*), having just read a context sentence such as "Jane tasted the tomato before it was ready to eat" or "Jane tasted the tomato when it was ready to eat" (either matching or mismatching the following ink color). In Stroop tasks, the effect of context depends on what has been primed: if the target word is primed, it *interferes* with naming ink color (Warren, 1972), whereas if the color name is primed, it *facilitates* naming ink color (Cheesman & Merikle, 1986; Kouider & Dupoux, 2004). The design used in this experiment always primes the target word (because it is always mentioned in the previous sentence) but primes the name of the color according to whether the context matches or mismatches. This manipulation therefore allows us to examine whether color-naming is being facilitated by object-typical or context-specific color.

Experiment

With a sentence such as "Jane tasted the tomato before it was ready to eat", people's canonical knowledge about tomatoes indicates that they are typically *red*, while their contextual representation of the scenario indicates that this particular tomato is likely to be *green*. In other words, when there are two possible colors for tomato (typical *red* and contextual *green*), which color is more likely to be activated when the word "tomato" is presented in isolation? Will participants experience more interference in naming ink color when "tomato" is displayed in red or in green? Previous research suggests different possibilities.

The first possibility is that canonical knowledge about color typicality will dominate, and that people will respond more quickly to atypical ink colors than to typical ink colors (regardless of the previous context). Naor-Raz et al. (2003)

demonstrate this, arguing that color-shape associations activated during lexical access (e.g., tomatoes are *red*) produce competition between the lexical entries for the object name and color name, thereby slowing access to the color name. While Naor-Raz et al. do not consider potential context effects, their account suggests that that any color-shape associations that arise upon reading the word "tomato" are canonical in nature and stem from long-term knowledge of tomatoes. In other words, canonical knowledge is activated on reading of a target word which causes participants to experience interference in accessing the name of the typical, canonical color (i.e., responses to typical slower than atypical).

The second possibility is that knowledge about context-specific color will dominate, and that people will respond more quickly when context matches the ink color than when it mismatches (regardless of the typicality of the ink color). Several studies have demonstrated the power of context in overriding canonical object information such as categorical typicality (Roth & Shoben, 1983) and property salience (McKoon & Ratcliff, 1988). According to this account, if the context implies that the tomato in question is *green* then participants will be faster to color-name if the target word is shown in green, because people's responses are facilitated if the ink color has been primed (Cheesman & Merikle, 1986; Kouider & Dupoux, 2004). Reading the target word will access participants' contextual knowledge and allow faster color-naming when the ink color matches the active, contextual color (i.e., match faster than mismatch).

There is a third possibility that predicts an interaction between canonical typicality and short-term context. According to Whitney et al. (1985), high-dominance properties produce interference regardless of context but low-dominance properties require a specifically biasing context to produce interference. To align property dominance and color typicality, this account suggests that typical ink colors will be activated regardless of context but atypical ink colors will require a specifically biasing context to be activated. Since priming the color name facilitates naming ink color (Cheesman & Merikle, 1986; Kouider & Dupoux, 2004), people will be faster to respond when the target word is shown in a typical color (e.g., "tomato" in red) and when the target word is shown in an atypical color (e.g., "tomato" in green) following a matching context. In short, reading the target word will access context-relevant knowledge (of either the typical object color or the context-specific atypical color) and facilitate color-naming when the ink color matches the active canonical/contextual color. In other words, typical and atypical match conditions will be responded to equally quickly, but both conditions will be faster than the atypical mismatch condition.

Method

Materials. Forty word/color combinations were created for use in this experiment. Of these, 20 used test words (object nouns with associated color typicality, forming pairs of typical and atypical ink colors: e.g., "tomato" in red and in green) and 20 were fillers (object nouns with no associated color, each displayed in a single ink color: e.g., "book" in turquoise). All ink colors used for test words were colored naturalistically by sampling shades from photographs of relevant objects, meaning that both typical and atypical versions represented possible (natural) colors for that particular object. A pretest of 12 independent raters confirmed that each chosen typical color (e.g., tomato-*red*) was considered more typical for that object than its atypical counterpart (e.g., tomato-*green*) at least 75% of the time (*M*=94%). Additionally, color saturation and luminosity were controlled between typical, atypical and filler ink colors.

Forty context sentences were constructed to accompany the target words. Of these, 20 were test sentences (featuring test words: see Appendix) and 20 were fillers (featuring filler words). Thus, the test sentences formed pairs, with each member of a pair implying a different color for the same object (i.e., matching and mismatching the ink color of the target word). Another pretest was conducted to ensure that the test sentences actually implied the intended object color. Pairs of test sentences were separated to form two groups of items and 24 new participants were randomly assigned to one of the groups. Each sentence was presented along with two line drawings of the target object, where one drawing was shaded using the object's typical color and the other using its atypical color. Participants were asked to choose, from four forced-choice alternatives, whether the sentence was best matched by a) the first picture, b) the second picture, c) both pictures equally, or d) neither picture. All test sentences used in this experiment had the picture from the matching condition chosen at least 50% of the time (*M*=83%). There were no differences between typical and atypical items (82% and 83% respectively).

Design. Test items were divided into four groups so that each group featured one of four combinations of context sentence and ink color: matching-typical, matching-atypical, mismatching-typical, mismatching-atypical. Each group contained equal numbers of match/mismatch and typical/atypical test items, and the various shades of color featured (reds, blues, etc.) were distributed approximately evenly across groups. Participants were assigned randomly to one of the groups. Thus, the experiment was a 2 (context: matching, mismatching) × 2 (ink color: typical, atypical) × 4 (group) design, with context and ink color as within-participants variables and group as a between-participants variable.

Participants. Forty-eight native speakers of English from Northumbria University (not involved in pretests) were paid a nominal sum for participation.

Procedure. Testing took place on portable computers running Presentation software. Participants read instructions describing the experiment that asked them to read each sentence to themselves (e.g., Jane tasted the tomato when it was ready to eat). They were told that a word from the sentence would then appear onscreen (e.g., tomato), and their task was to name the color of the text, out loud and as quickly as possible, using short color names. Participants were also told that quick responses were important because their response time was being measured, and to read every sentence carefully as their comprehension would be tested at various points during the experiment. A light grey screen background was used throughout the experiment to optimize visibility of every stimulus color. Each trial began with a left-aligned vertically-centred fixation cross presented for 1000ms, followed by presentation of a sentence. When participants pressed the space bar to indicate comprehension, another fixation cross was displayed centrally onscreen for 500ms, followed by a single word. Participants had to name aloud the ink color of the displayed word as quickly as possible. Response times were measured from the presentation of the stimulus to the voice-triggered response. In half of all filler trials, a comprehension question (relating to the filler sentence) appeared after color-naming and participants indicated their decision by pressing the key labelled "yes" (the comma key) or "no" (the full-stop key). Each participant was required to answer an equal number of "yes" and "no" comprehension questions. A blank screen was displayed for 500ms as an inter-stimulus break between trials. Including a practice session to allow participants to become accustomed to the voice-response task, the entire procedure took approximately 10 minutes.

Analysis. Four participants responded incorrectly to >50% of the comprehension questions and were eliminated from the analysis. All responses <300ms and >2000ms were considered outliers and dropped from the analysis, as were any responses more than two standard deviations away from a participant's mean in the relevant condition: in total, less than 5% of the data was excluded. Color-naming responses were considered to be correct if the experimenters considered the named color to be a reasonable approximation of the color displayed: (e.g., the color for "chameleon" in the typical condition was considered correct if named as "yellow" or "orange" but not "red" or "blue"). Responses that contained disfluencies or self-corrections were removed prior to analysis. Analyses of variance were performed on correct responses by participants (F_1) and by items (F_2).

Results & Discussion

Results were consistent with the view that canonical typicality and short-term context interact, and that color-naming can be facilitated by both object-typical and context-specific color. Figure 1 shows the mean correct response times (in ms) for the context × ink color conditions (matching typical M=984, SD=306; mismatching typical M=909, SD=281; matching atypical M=912, SD=269; mismatching atypical M=1083, SD=276). Error rates were approximately equal across all conditions (matching typical =95%, all other conditions=96%).

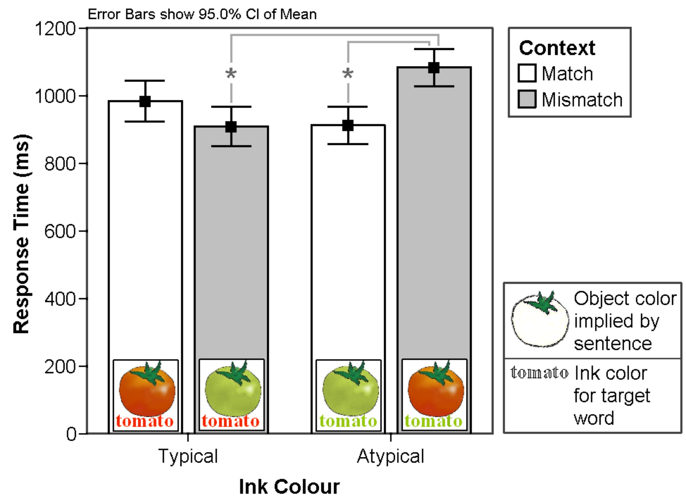

Figure 1. Mean color-naming times (ms) per context and ink color. '*' indicates a reliable difference between conditions.

There was no main effect of either context [$F_1(1,39)=3.929$, $MSE=37459$, $p=0.055$; $F_2(1,24)=2.295$, $MSE=11187$, $p=0.143$] or ink color [F_1 & $F_2<1.13$] [1]. However, the interaction of context and ink color was reliable [$F_1(1,39)=8.688$, $MSE=42034$, $p=0.005$; $F_2(1,24)=5.174$, $MSE=11187$, $p=0.032$]. When the ink color was typical for that object (e.g., "tomato" in *red*), the preceding sentence (matching or mismatching) made no difference to how quickly people were able to name the color [F_1 & $F_2<1$]. On the other hand, when the ink color was atypical (e.g., "tomato" in *green*), people were faster to name the color when it *matched* the preceding context sentence than when it *mismatched* [$F_1(1,39)=13.278$, $MSE=36752$, $p=0.001$; $F_2(1,12)=12.885$, $MSE=6234$, $p=0.004$]. It is also useful to view the results from the perspective of the context variable. When the context matched the ink color, there was no difference in naming times for typical and atypical ink colors [$F_1(1,39)=3.000$, $MSE=32942$, $p=0.091$; $F_2(1,12)=1.071$, $MSE=14362$, $p=0.321$]. In contrast, when the context mismatched, people responded more quickly to typical ink colors (e.g., "tomato" shown in *red* after sentence implies *green*) than to atypical colors (e.g., "tomato" shown in *green* after sentence implies *red*) [$F_1(1,39)=9.200$, $MSE=31726$, $p=0.004$; $F_2(1,12)=5.834$, $MSE=8013$, $p=0.033$].

General Discussion

In this study, canonical typicality and context effects on object representation are examined with respect to color information in a novel application of the semantic Stroop paradigm. Results showed that both canonical and context-

[1] The group variable had no main effect and is not reported further due to its lack of theoretical importance.

specific perceptual information interact: color naming was fastest both when ink color was typical for that object and when it matched the color implied by the previous sentence. This finding is in line with previous research on property dominance, and is also compatible with embodied theories of representation which state that perceptual information is activated during sentence comprehension.

It is interesting to note that canonical-contextual reinforcement – where the context implies an already typical color – did not result in the fastest response times. Rather, the fastest naming times were determined by context: people responded quickly (regardless of ink color) where the context sentence implied an atypical color (909 ms and 912 ms for the Mismatching Typical and Matching Atypical respectively). This finding suggests that when an object has an associated, typical color (such as a tomato being typically *red*, or a bear being typically *brown*), encountering a context where it has a different color causes the object to be represented with both typical and contextual color information. In other words, these results suggest that context does not overwrite typical color in object representations, but rather it causes both to be held in mind.

Regarding previous Stroop research, these findings suggest that Naor-Raz et al.'s (2003) results (participants were slower to name typical colors) do not generalize to the presence of context. People in this study did not experience interference in naming typical ink colors because of the priming action of the preceding context (see process model below). Indeed, rather than context being an overwhelming influence, this study found that typical colors are activated regardless of context but atypical ink colors require a specifically biasing context to be activated, much like Whitney et al.'s (1985) examination of property dominance. Regarding theories of embodied or situated cognition (see Wilson, 2002, for review), previous research has shown that implied perceptual information is activated during sentence comprehension even though doing so does not facilitate task performance (Connell, in press.; Stanfield & Zwaan, 2001; Zwaan, Stanfield & Yaxley, 2002). Color representation is usually described as the specialization of a perceptual simulation to include color information (Barsalou, 1999; Zwaan, 2004). However, there has been little discussion of how such specialization might take place if the object simulation is already specialized with a typical color. This paper shows (see also Connell, in press) that implicit perceptual information on object color is represented during language comprehension, and suggests that a context-specific specialization can be held in parallel with the more usual, typical specialization of an object. Echoes of these findings can be found in Kaup, Lüdtke and Zwaan (in press) who suggest that both "expected" and "actual" properties may be represented simultaneously in language comprehension.

For example, a process model of the task might proceed as follows. First, people read the context sentence. If object-typical color is implied then nothing out of the ordinary has happened and the object retains its usual specialization of the typical color (e.g., *red* tomato with high activation of *red*). However, if object-atypical color is implied then something unusual is afoot and the object is represented with a parallel specialization of both typical and atypical colors (e.g., *red|green* tomato with both colors at high activation). Second, people see the target word. If the ink color is typical then people's responses are facilitated because the color has been primed by either the matching or mismatching context (e.g., highly activated *red* in tomato or highly activated *red|green* in tomato, respectively, both facilitate "tomato" in *red*). If the ink color is atypical then color-naming is also facilitated by matching context (e.g., highly activated *red|green* in tomato facilitates "tomato" in *green*). On the other hand, atypical ink color following a mismatching context does will not be facilitated (e.g., highly activated *red* in tomato does not facilitate "tomato" in *green*). Therefore, we see fastest naming times in the matching-atypical and mismatching-typical conditions, followed by the slightly slower matching-typical condition, followed by the significantly slower mismatching-typical condition (as shown in Figure 1).

It could be argued that people are not merely specializing object color in such scenarios, but rather are specializing the subcategorization of the object (e.g., categorizing from generic *bear* to specialized *polar bear* or *grizzly bear*, or from generic *tomato* to specialized *ripe tomato* or *unripe tomato*). However, in terms of embodied representations this is not a matter of particular concern. A simulation of a *green tomato* will also carry other sensorimotor information previously experienced regarding such tomatoes, perhaps including its texture (harder and crisper than ordinary red tomatoes) and taste (sharper and milder than ordinary red tomatoes). The fact that this tomato may now be labeled an "unripe tomato" is secondary to the specialization itself.

The findings reported here offer an insight into how the well-documented phenomena of typicality and context effects actually interact during comprehension of implied perceptual information. Parallel specialization, where typical object information is held in mind in the face of contradictory context, offers several advantages to the language comprehender, such as allowing for easy error correction and rapid identification of other (more typical) exemplars. Further research is needed to investigate the implications of such possibilities.

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Appendix

40 test items were created from 10 base sentences x 2 (Match/Mismatch) x 2 (Typical/Atypical) conditions. The following context sentences are presented as [typical / atypical] variants → *target word*: typical color / atypical color:

- Jane tasted the tomato [when / before] it was ready to eat. → *tomato*: red / green
- Joe was excited to see a bear [in the woods / at the north pole]. → *bear*: brown / white
- Paula thought the tree outside her window looked beautiful in the [summer / autumn]. → *tree*: green / orange
- John looked at the steak [on his plate / in the butcher’s window]. → *steak*: brown / red
- The children watched the seagulls fly across the sky in the [sunshine / rain]. → *sky*: blue / grey
- Susan liked it when her [granddaughter / grandmother] wore her hair up. → *hair*: brown / grey
- Anna found it very [easy / difficult] to spot the lamb in the dark grass. → *lamb*: white / black
- Sarah stopped in the woods to pick a leaf off [a tree / the ground]. → *leaf*: green / orange
- The bananas that Mark bought [looked / didn't look] ready to eat. → *bananas*: yellow / green
- The teacher pointed to the chameleon lying camouflaged in the [grass / sand]. → *chameleon*: green / yellow