Redundant color words are more efficient than shorter descriptions

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Abstract

It is well documented that people use color words when it is not necessary. This type of redundancy challenges influential work from cognitive science and philosophy suggesting that communication is efficient. The results of an eye-tracking study explain these seemingly contradictory findings by confirming the visual efficiency hypothesis: redundant color words can facilitate the listener's visual search for a referent, despite making the description unnecessarily long. That is, participants were faster to find 'the blue star' than 'the star' in a display of shapes with only one star. It is proposed that a referential expression's efficiency should be based not only on its informational value, but also on its discriminatory value, which means that redundant color words can be more efficient than shorter descriptions.

Keywords: reference, color adjectives, redundant information, visual search.

In the last decade, research in cognitive science has uncovered how human language is shaped by a pressure to communicate efficiently (Gibson et al., 2019). Yet contrary to this view, experimental studies have repeatedly shown that people often use adjectives (especially color) when it is not necessary (e.g., Sonnenschein & Whitehurst, 1982; Mangold & Paraboni, 1988; Belke & Meyer, 2002; Sedivy, 2003, 2004; Maes et al., 2004; Belke, 2006; Paraboni et al., 2007; Paraboni & van Deemter, 2014). For example, people may say ‘Pass me the blue bowl’ when there is only one bowl on the table, instead of using the shorter instruction ‘Pass me the bowl’. This has presented a challenge to the standard theory of communication proposed by philosopher Paul Grice (1975), according to which speakers should not make their contributions more informative than necessary. Here an alternative hypothesis was tested, namely the visual efficiency hypothesis, which explains this behavior as rational and cooperative (Rubio-Fernandez, 2016, 2019): redundant color words may facilitate the listener’s visual search for a referent relative to shorter descriptions.

What counts as an efficient referential expression?

In line with the Gricean view, the general assumption in the experimental literature is that shorter referential expressions are preferable over redundant ones because the latter require extra effort to produce and time to process, with no added informational value (e.g., Pechmann, 1988; Engelhardt et al., 2006, 2011; Koolen et al., 2013). Thus, color words should only be used when they are necessary (e.g., to distinguish two bowls of different colors) and therefore have informational value; otherwise shorter descriptions are preferred. However, this standard view

of referential efficiency is based solely on information quantity (measured in number of words) and fails to account for perceptual factors.

Perception is tightly related to reference: as a speech act, the goal of reference is to ensure that the listener identifies the intended referent in the context. In this view, an efficient referential expression is one that achieves this goal fast and easily (Rubio-Fernandez, 2016, 2019). Providing sufficient information for the listener to identify a referent undoubtedly contributes to a referential expression's efficiency, since otherwise the listener is left to guess or ask for clarification. However, the relative ease or difficulty of the listener's visual search must also count towards the referential expression's efficiency. Thus, even if a redundant color word does not have informational value, it may have discriminatory value if it facilitates the listener's identification of the referent in the visual context.

Imagine a situation with a single bowl on a breakfast table: the description 'the blue bowl' would be equally overinformative if the bowl was the only blue object on the table, or if all the tableware were blue. Yet for visual search, the word 'blue' is clearly more efficient when it is a distinctive property of the referent than when all objects are the same color (Rubio-Fernandez, 2016, 2019). More generally, an extensive literature on visual cognition has shown that color plays a key role in object recognition (Bramão et al., 2011). Therefore, under the visual efficiency hypothesis, a redundant color word may have discriminatory value that contributes to a referential expression's efficiency, above and beyond its informational value, and it is ultimately an empirical question whether redundant color words may sufficiently facilitate the visual search for a referent to be more efficient than shorter descriptions. This empirical question was the focus of the present study.

Previous studies on the effect of overinformativity

Supporting the traditional view that redundancy is inefficient, several psycholinguistic studies have shown that redundant descriptions can impair communication (Eberhardt et al., 2006, 2011; Davies & Katsos, 2013). However, upon closer inspection of their materials, the redundant information used in these studies may not have had discriminatory value that could facilitate visual search. For example, Eberhardt et al. (2006) used complex descriptions such as ‘Put the apple on the towel in the box’, where the overinformative phrase ‘on the towel’ could refer to the current location of the apple or to its destination, creating a temporary ambiguity that should delay visual search rather than facilitate it.

More directly comparable to the present study, Eberhardt et al. (2011) reported that redundant descriptions like ‘Look at the red square’ delayed target identification in displays with two shapes, even though color was a distinctive property of the target. Eberhardt and colleagues concluded that redundant information impairs communication, yet their results could be related to the sparse displays they employed. This is relevant to the visual efficiency hypothesis because a property’s discriminatory value does not solely depend on its distinctiveness, but also on the density of the display, with redundant color words being more efficient in denser displays where the listener’s visual search is harder (Rubio-Fernandez, 2019). Supporting this view, a number of studies have shown that redundant referential expressions are more frequent in denser displays (e.g., Paraboni et al., 2007; Clarke et al., 2013; Koolen et al., 2015; Gatt et al., 2017). In particular, Rubio-Fernandez (2019) observed that in two-shape displays, people overspecified color around 20 percent of the time, whereas they did so over 80 percent of the time in denser

displays. It is therefore an open question whether redundant color words would facilitate visual search in denser displays, where redundant color words are more frequently produced.

Finally, Davies and Katsos (2013) observed delayed response times with redundant descriptions such as ‘Pass me the small star’ in displays of four objects. However, Davies and Katsos pretested their materials and only used properties that were not frequently overspecified in a language production task. Again, this leaves open the possibility that properties that are frequently overspecified (such as color) may have facilitated participants’ visual search.

Supporting the hypothesis that redundant adjectives can be visually efficient (Rubio-Fernandez, 2016, 2019), a number of studies have shown that redundant properties such as color, size and position can sometimes reduce referent identification times (Sonnenschein & Whitehurst, 1982; Mangold & Pobel, 1988; Paraboni et al., 2007; Arts et al., 2011; Paraboni & Van Deemter, 2014). However, these studies used off-line tasks (e.g., participants had to read a target description before searching for it in a display, or they had to navigate a virtual environment following overinformative spatial descriptions). Processing a description ahead of time could allow participants to build a more detailed mental representation of the target that could later facilitate its identification, yet this facilitation may not be observed in real-time language processing (Engelhardt & Ferreira, 2016). Monitoring visual search during language processing would therefore offer a better test of the visual efficiency hypothesis.

Prior work on visual attention has shown that real-time language interpretation can constrain visual perception; in particular, the incremental processing of a spoken instruction results in the listener’s search being less affected by the number of distractors (as in feature search tasks; Treisman & Gelade, 1980; Spivey et al., 2001; Reali et al., 2006). Eye-tracking

studies investigating real-time language interpretation have compared the processing of modified instructions (e.g., ‘Click on the blue star’) when color was necessary to distinguish two competitors and when it was redundant (Sedivy, 2003, 2004; Grodner & Sedivy, 2011; Tourtouri et al, 2019; see also Engelhardt et al., 2011). However, these studies do not speak to the issue of whether redundant color words can facilitate the visual search for a referent. To investigate that question, listeners’ eye movements and response times should be compared during the processing of redundant and minimal instructions (e.g., ‘Click on the blue star’ vs. ‘Click on the star’) in the same visual display.

Moreover, comparing the processing of modified descriptions when color is necessary or redundant cannot explain why people use color words redundantly (cf. Tourtouri et al., 2019). When presented with a display with a single star, for example, speakers do not have the choice to ‘throw in’ a second star and make their color adjective contrastive. However, that is essentially what the above studies compared in order to explain color overspecification. The choice that a speaker faces in that situation is whether or not to mention the color of the star, and the question therefore remains: would asking for ‘the blue star’ facilitate the listener’s visual search relative to the shorter description ‘the star’? Addressing this key question was the aim of this study.

Experiment

Methods

Participants

A group of 40 students from University College London took part in the experiment. They were native speakers of English and participated for monetary compensation. All participants reported having normal colour vision. Sample size was based on a previous cross-linguistic study using the same paradigm (Rubio-Fernandez et al., under review).

Materials and procedure

All visual materials used in the experiment are available at OSF

(https://osf.io/38m2h/?view_only=1292f98c00fa4d71abec0f1f91d38ff2). The materials included 8 displays from each of the following conditions: Polychrome/4, Polychrome/8, Pop-Out/8 and Non-Pop-Out/8 (for sample displays, see Figs. 1A-1D). An extra 8 slides (2 from each condition) were used as warm-up trials and were not analysed.

The aim of the Non-Pop-Out/8 condition was twofold: first, it prevented participants from anticipating the target in the Pop-Out/8 condition. Second, it allowed comparing the processing of redundant colour adjectives when color is distinctive of the target (Poly/4, Poly/8 and Pop-Out/8, abbreviated) and when it is not (Non-Pop-Out/8). This is an important comparison because current pragmatic models do not predict a difference between the two, whereas the visual efficiency hypothesis makes reverse predictions depending on whether color is distinctive or not.

The displays were on the screen for 400ms before the instruction started. The instructions were recorded by a male speaker of British English, who did not stress the adjectives contrastively. Each display was paired with two different instructions: one redundant (e.g., 'Click on the blue star') and a minimal one (e.g., 'Click on the star'). The visual materials were

presented twice during the task in two separate blocks: one in the Redundant condition and another in the Minimal condition. Between each block there was a 20s break. The order of the items was randomized within each block and the order of the blocks was counterbalanced in two separate lists of materials, which were randomly distributed.

Participants were told that they were going to listen to a series of instructions to click on different shapes and their task was to click on the target as fast and accurately as possible. In between trials, they had to click on a cross in the centre of the screen, which ensured that the mouse cursor was always in the centre of the screen at the start of each trial.

Eye movements were recorded with a portable eye-tracking system (RED-m by SMI) that measured eye position at a sampling rate of 120 Hz and had a spatial resolution (RMS) of 0.1° and an accuracy of 0.5°. Participants were seated about 60 cm from the computer screen. The contact-free set up of the system allowed free head-movement during eye tracking. The experiment lasted approximately 15 minutes.

Processing measures of (i) delay of first target fixation, (ii) percentage of target fixations in the critical time window, and (iii) response times were collected. Response times were measured from the onset of the instruction, whereas first target fixations were measured from the onset of the first word in the instruction that could distinguish the target (i.e. the color adjective in the Redundant condition and the shape noun in the Minimal condition). In the Redundant condition, the critical time window was calculated from the onset of the adjective until the offset of the noun. In the Minimal condition, the critical time window started at noun onset and included an equivalent silence after the noun (i.e. [ADJECTIVE + NOUN] = [NOUN + SILENCE]; M = 900ms).

It was predicted that, if redundant color adjectives are visually efficient, an advantage should be observed in the Redundant condition when color is a distinctive property of the target (Poly/4, Poly/8 and Pop-Out/8), whereas a disadvantage should be observed when color is not distinctive, as the adjective creates a temporary ambiguity during processing (Non-Pop-Out/8).

Results

All data and analysis code are available at OSF

(https://osf.io/38m2h/?view_only=1292f98c00fa4d71abec0f1f91d38ff2). Proportions of target fixations during the processing of redundant and minimal instructions in the four display types are plotted in Figs. 1A-1D.

Figures 1A-1D: Proportions of target fixations during the processing of redundant instructions ('Click on the blue star') and minimal instructions ('Click on the star') in conditions (A) Polychrome/4, (B) Polychrome/8, (C) Pop-Out/8 and (D) Non-Pop-Out/8.

Linear mixed effects regression was used for each of the processing measures, modelling the fixed effects of Display and Instruction, including Participants and Items as random effects, and the maximal random effect structure (for model outputs, see Table 1). The Non-Pop-Out/8 – Minimal condition was dummy-coded as the reference level because it was the only condition where color was not a distinctive property of the target. It was therefore predicted that color adjectives would have the reverse effect in the other display types (Poly/4, Poly/8 and Pop-Out/8; see Figs. 2A-2C). Each model was fit using the lme4 package (Bates et al., 2014) under the statistical computing language R (Version 1.2.1335; R Core Team, 2018).

For each of the three processing measures, there was a main effect of Instruction in Non-Pop-Out/8: redundant instructions resulted in slower first target fixations ($\beta = 250.18$; $t = 5.35$), lower percentages of target fixations during the critical time window ($\beta = -17.92$; $t = -4.29$) and slower response times ($\beta = 341.75$; $t = 5.22$) than the minimal instructions. The Display x Instruction interactions were as predicted: relative to the displays where color was not distinctive, redundant color adjectives sped up first target fixation in Poly/4 ($\beta = -353.17$; $t = -7.39$), Poly/8 ($\beta = -400.11$; $t = -6.92$) and Pop-Out/8 ($\beta = -380.90$; $t = -7.58$). Redundant color adjectives also increased the percentage of target fixations during the critical time window in Poly/4 ($\beta = 24.54$; $t = 5.02$), Poly/8 ($\beta = 34.34$; $t = 5.79$) and Pop-Out/8 ($\beta = 28.77$; $t = 6.62$) relative to Non-Pop-Out/8. Finally, redundant color adjectives reduced response times when

color was distinctive of the target (Poly/4: $\beta = -421.41$; $t = -4.60$; Poly/8: $\beta = -468.34$; $t = -4.55$; Pop-Out/8: $\beta = -488.86$; $t = -6.43$).

Figures 2: (A) Mean delay of first target fixation and (B) mean RTs by Display and Instruction type. (C) Mean percentages of target fixations during the critical time window. Non-Pop-Out/8 was the only condition where color did not discriminate the target. Error bars indicate 95% bootstrapped confidence intervals.

Measure	Fixed effects	Estimate	Std. Error	t-value
First target fixation	Intercept	1252.78	96.67	12.96
	Poly/4	-165.46	106.60	-1.55
	Poly/8	-65.36	119.51	-0.55
	Pop-Out/8	-238.31	111.40	-2.14
	Redundant	250.18	46.79	5.35
	Poly/4 vs Redundant	-353.17	47.83	-7.39

	Poly/8 vs Redundant	-400.11	57.83	-6.92
	Pop-Out/8 vs Redundant	-380.90	50.24	-7.58
Percentage of target fixations	Intercept	39.17	6.62	5.92
	Poly/4	15.01	7.66	1.96
	Poly/8	2.24	8.46	0.27
	Pop-Out/8	15.83	6.81	2.33
	Redundant	-17.92	4.18	-4.29
	Poly/4 vs Redundant	24.54	4.89	5.02
	Poly/8 vs Redundant	34.34	5.93	5.79
	Pop-Out/8 vs Redundant	28.77	4.34	6.62
	Intercept	2042.51	102.85	19.86
Response times	Poly/4	-188.12	128.92	-1.46
	Poly/8	-53.39	128.17	-0.42
	Pop-Out/8	-231.58	129.00	-1.80
	Redundant	341.75	65.47	5.22
	Poly/4 vs Redundant	-421.41	91.67	-4.60
	Poly/8 vs Redundant	-468.34	103.03	-4.55
	Pop-Out/8 vs Redundant	-488.86	75.98	-6.43
	Intercept	2042.51	102.85	19.86

Table 1: Results of logistic mixed effect models for each processing measure, positing fixed effects of Display and Adjective plus their interaction, with random effects of Subject and Item, and the maximal random effect structure. Non-Pop-Out/8 – Minimal was dummy coded as the reference level (with Non-Pop-Out/8 being the only display where color was not distinctive of the target).

Comparing models with and without the interaction term between Display and Modification (holding random effect structure constant) revealed a highly significant interaction between the two factors in each of the measures (First target fixation: $X^2(3) = 21.19$, $p < .0001$; Percentage of target fixations: $X^2(3) = 17.60$, $p < .0006$; Response times: $X^2(3) = 16.64$, $p < .0009$), supporting the visual efficiency hypothesis.

General discussion

Results from all three processing measures confirmed that redundant color descriptions can speed up target identification relative to shorter descriptions. Although they may require more effort to produce and a longer time to process, redundant color descriptions are efficient in facilitating the listener's visual search for the referent. These findings highlight the importance of perceptual factors (and not only information quantity) when calculating a referential expression's efficiency (Rubio-Fernandez, 2016, 2019). Here participants identified 'the blue star' faster than 'the star' when the star was the only blue shape in the display, but they were faster to follow the shorter instruction when most shapes were blue. Because color was redundant in both situations, current pragmatics models based on information quantity fall short of explaining this pattern of results. More importantly for our understanding of communication, current models fail to explain why people often use color words redundantly.

Supporting the visual efficiency hypothesis, previous studies have shown that people tend to use redundant color words in polychrome displays where color is a distinctive property

of the target, but rarely in monochrome displays where color has low discriminatory value (Belke, 2006; Koolen et al., 2013; Rubio-Fernandez, 2016, 2019). I have recently proposed that in situations of co-presence (where speaker and listener share a physical space), speakers can rely on visual heuristics that can inform their choice of referential expression at a low processing cost (Rubio-Fernandez, 2019; see also Clark & Marshall, 1981). For example, the understanding that color is more efficient in polychrome than in monochrome displays could be applied as a visual heuristic triggered by the perception of color contrast. This type of low-cost pragmatics is in line with Ferreira's (2019) feedforward audience design, according to which speakers need not engage in reflective processes to be sensitive to their interlocutor's needs; instead, they can make use of contextual cues prior to the onset of utterance production and rely on previously learned strategies that facilitate communication.

In conclusion, the results of this study offer an answer to a 40-year debate: psycholinguistic studies reporting that people often use color words redundantly need not challenge the views from cognitive science and philosophy of language on efficient communication (Grice, 1975; Gibson et al., 2019). If we assume that a referential expression's efficiency is based not only on its informational value but also on its discriminatory value, then redundant color words can be more efficient than shorter descriptions, facilitating coordination between speakers and listeners.

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