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Absence of distracting information explains the redundant signals effect for a centrally presented categorization task☆

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ABSTRACT

The redundant signals effect, a speed-up in response times with multiple targets compared to a single target in one display, is well-documented, with some evidence suggesting that it can occur even in conceptual processing when targets are presented bilaterally. The current study was designed to determine whether or not category-based redundant signals can speed up processing even without bilateral presentation. Toward that end, participants performed a go/no-go visual task in which they responded only to members of the target category (i.e., they responded only to numbers and did not respond to letters). Numbers and letters were presented along an imaginary vertical line in the center of the visual field. When the single signal trials contained a nontarget letter (Experiment 1), there was a significant redundant signals effect. The effect was not significant when the single-signal trials did not contain a nontarget letter (Experiments 2 and 3). The results indicate that, when targets are defined categorically and not presented bilaterally, the redundant signals effect may be an effect of reducing the presence of information that draws attention away from the target. This suggests that redundant signals may not speed up conceptual processing when interhemispheric presentation is not available.

1. Introduction

The presence of redundant information within a display provides a stronger signal to which people respond more quickly than they would without redundancy (e.g., Miller, 1982; Raab, 1962). This has been demonstrated with simple response time (RT) tasks, choice RT tasks, and go/no-go tasks (Miller, 2004). It has been demonstrated both with signals in different modalities, such as one visual and one auditory stimulus (e.g., Diederich, 1995; Diederich & Colonius, 1987; Miller, 1982, 1986), and with unimodal signals, such as two visual stimuli (e.g., Forster, Cavina-Pratesi, Aglioti, & Berluchhi, 2002; Schwarz & Ischebeck, 1994), although the effect is sometimes dependent on displaying targets bilaterally (e.g., Corballis, Hamm, Barnett, & Corballis, 2002). Some evidence also suggests that the redundant signals effect can be elicited at more abstract levels of information processing, although the effect is sometimes confounded with an effect of removing nontarget stimuli. The current study was conducted to determine whether or not redundancy gain can occur in categorical processing, even without bilateral stimulus configurations, or if there will only be an advantage of removing nontarget stimuli and no advantage of adding an extra target.

Research has indicated multiple cognitive or neurological loci for the redundant signals effect in RT. Some researchers have found behavioral and neural evidence for the redundant signals effect in early visual processing (Corballis, 2002; Lobaugh, Chevalier, Batty, & Taylor, 2005; Miniussi, Girelli, & Marzi, 1998; Zehetleitner, Krummenacher, & Müller, 2009; but see Miller, Kühlwein, & Ulrich, 2004), even as early as the stage of sensory persistence (Savazzi & Marzi, 2008). Others have found evidence for the redundant signals effect at a later stage of processing (e.g., Iacoboni & Zaidel, 2003; Schwarz, 2006), with some specifically suggesting that the effect might occur at the response-selection level (e.g., Akyürek & Schubö, 2013; Miller, 1982). Schwarz (2006) argued that an increased redundant signals effect in people with split brains (e.g., Corballis et al., 2002; Roser & Corballis, 2002, 2003) is further evidence that the redundant signals effect occurs at post-perceptual levels. Roser and Corballis also presented evidence that the redundant signals effect in people with split brains did not depend on bilateral symmetry between redundant targets (Roser & Corballis, 2002), nor did it occur when a target stimulus was presented with a non-target stimulus (Roser & Corballis, 2003). They concluded that the redundant signals effect, at least in people with split brains, may occur at the level of response selection. Evidence seems to be opposed to the presence of a redundant signals effect in the speed of motor response execution

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(Miller, Ulrich, & Lamarre, 2001; Mordkoff, Miller, & Roch, 1996), although redundant signals may affect motor processing in ways not related to speed (Cavina-Pratesi, Bricolo, Prior, & Marzi, 2001; Diederich & Colonius, 1987; Giray & Ulrich, 1993; Plat, Praamstra, & Horstink, 2000).

Overall, the data suggest that the redundant signals effect can occur both in basic visual processing and in higher-level processing, including response-selection mechanisms. The question becomes in what higher-level processing mechanisms the redundant signals effect can be found; for example, is it possible for the redundant signals effect to occur in conceptual processing? If a redundant signals task is designed such that object categorization is needed to complete the task, then a significant redundant signals effect would indicate a speed-up in category-based decision making. Evidence from previous research suggests that categorization of visual objects occurs after early visual processing. The category of a visual stimulus, including letters, does not affect processing until after visual analysis (Pernet et al., 2003). Instead, Pernet et al. found N2 and P2 EEG components were the earliest to be affected by the category of a visual stimulus, suggesting that processing related to categories begins at the level of matching the stimulus to a representation. Additionally, Dick (1971) found that naming the category of a visual stimulus takes longer than naming its identity, and concluded that identification precedes categorization, a conclusion also reached in a review by Reed (1973). However, Posner (1970) and Taylor (1978) also found a faster RT for stimulus identification than for stimulus categorization, but concluded that identification and categorization occur as parallel, independent processes, given that RT for categorization tasks is not always affected by manipulations, such as acoustic similarity between letters, that affect RT in identification tasks. Regardless of their independence, categorization appears to be a consistently longer process than identification (Taylor, 1978). Additionally, at least for letters and digits, categorization effects can occur even for a target that is physically identical to an item in the opposite category (The letter O and the number 0; Jonides & Gleitman, 1972), leading Reed (1973) to conclude that categorization is not based on a particular conjunction of physical features that might differ between letters and numbers. All of the above evidence suggests that categorization occurs at a higher level than visual analysis, and that categorization is either a different and longer type of processing, or a higher level of processing than stimulus identification. Redundancy gain for categorical stimuli therefore would indicate a redundant signals effect not only beyond the level of early visual processing, but specifically within the level of stimulus categorization.

A few experiments that have been conducted to address this possibility indicate that a conceptual-level redundant signals effect may be possible, at least for bilateral target presentation. However, some of the experiments that have demonstrated an apparent redundancy gain in conceptual processing of visual stimuli may have confounded a favorable effect of redundancy with an unfavorable effect of distracting information. Marks and Hellige (2003) asked participants to read letter trigrams and number trigrams, presented unilaterally (single signals); or presented bilaterally (redundant signals), in either the same format or two different formats (upper and lower case for letter trigrams, digits and dot patterns for number trigrams). For letter trigrams, accuracy actually improved slightly when redundant trigrams were presented in different cases compared to identical cases; for number trigrams, accuracy decreased when redundant trigrams were presented in different format, but was still higher than for single trigrams. Marks and Hellige thus demonstrated that there is some effect of redundant signals at an abstract level of processing, although their paradigm did not lend itself to RT measures specifically.

There is also a possibility that Marks and Hellige did not actually find a benefit of redundancy, but instead found a benefit of removing irrelevant information from the display. In their single signal trials, noise stimuli were used for the positions that did not contain target stimuli. In the redundant signal trials, those noise stimuli were replaced with another set of target stimuli. As a result, redundant signals trials not only increased the number of target signals available, but also reduced the number of noise signals. In studies of specific (non-categorical) redundant signals, there is evidence that the redundant signals effect can be reduced by removing non-target signals from the single signal conditions (e.g., Miller, 1982), although eliminating nontargets does not always reduce the effect (Allen, Groth, Weber, & Madden, 1993; Grice & Canham, 1990). It is therefore possible that redundant signals trials were more accurate in Marks and Hellige (2003), not because the additional signal enhanced accuracy in redundant signal trials, but because the noise stimuli distracted participants and therefore reduced accuracy in single signal trials. Such an interpretation would not be surprising, given that irrelevant stimuli often degrade performance in responding to visual stimuli (e.g., Bjork & Murray, 1977; Eriksen & Eriksen, 1974).

Marks and Hellige (2003) examined the redundant signals effect with respect to accuracy rather than RT. Reinholz and Pollman (2007), however, did examine RT for bilaterally-presented redundant categorical targets. They asked participants to make speeded judgments about whether or not stimuli belonged to a particular category (either faces or buildings), and found that responses were significantly faster with redundant targets than with single targets. However, some caution is necessary in interpreting their results, as the target category switched between faces and buildings within participants. In the single signal trials, targets were sometimes paired with a scrambled stimulus and sometimes paired with a stimulus from the opposite target category (e.g., a face target would be paired with a building non-target). The only significant difference in RT was the difference between redundant targets and single target + other-category stimulus; the difference between redundant targets and single target + scrambled stimulus was not significant. This indicates that the effect on RT was not necessarily due to a redundancy-related decrease in RT, but may instead have been due to an increase in RT during single signal trials in which a previous target interfered with current target processing. Thus, Reinholz and Pollman's research, like that of Marks and Hellige (2003) may have shown an advantage of eliminating information that pulled attention away from the targets, rather than an advantage of additional targets in the display.

Other research, which also employed bilaterally-presented stimuli, suggests that face familiarity judgments can benefit from redundancy even when it takes the form of two different photographs of the same famous person (Mohr, Landgrebe, & Schweinberger, 2002; Schweinberger, Baird, Blümler, Kaufmann, & Mohr, 2003). Emotion recognition judgments may also benefit from bilateral redundancy, even when the redundancy is presented as two different faces expressing the same emotion (Tamietto, Adenzato, Geminiani, & de Gelder, 2007; Tamietto, Latini Corazzini, de Gelder, & Geminiani, 2005). Although not explicitly testing redundancy gain for discrete categories, these studies indicate that processing of bilaterally-presented categorical information is susceptible to redundancy gain.

Consequently, it appears likely that redundancy gain can occur for categorical stimuli. However, the experiments discussed above all employed bilateral redundant stimuli. In the case of non-categorical redundant signals, presenting multiple stimuli to one visual hemifield often does lead to redundancy gain, but redundancy gain is often stronger when stimuli are presented to separate visual hemifields (Corballis et al., 2002; Girard, Pelland, Lepore, & Collignon, 2013; Schulte, Pfefferbaum, & Sullivan, 2004; but see Ouimet et al., 2009). Additionally, experiments in which non-categorical targets are presented on the vertical midline of vision often show that what appears to be redundancy gain is mostly or entirely eliminated when noise stimuli are removed from single-signal conditions (Grice & Canham, 1990; Grice, Canham, & Boroughs, 1984; Grice & Gwynne, 1987; Grice & Reed, 1992), although some research shows a robust redundancy gain for vertical midline displays, regardless of noise (Allen, Weber, & Madden, 1994). These results indicate that the opportunity to