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# Shape and color naming are inherently asymmetrical: Evidence from practice-based interference

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ABSTRACT

Stroop interference is characterized by strong asymmetry between word and color naming such that the former is faster and interferes with the latter but not vice versa. This asymmetry is attributed to differential experience with naming in the two dimensions, i.e., words and colors. Here we show that training on visual-verbal paired associate tasks equivalent to color and shape naming, not involving word reading, leads to strongly asymmetric interference patterns. In two experiments adults practiced naming colors and shapes, one dimension more extensively (10 days) than the other (2 days), depending on group assignment. One experiment used novel shapes (ideograms) and the other familiar geometric shapes, associated with nonsense syllables. In a third experiment participants practiced naming either colors or shapes using cross-category shape and color names, respectively, for 12 days. Across experiments, despite equal training of the two groups in naming the two different dimensions, color naming was strongly affected by shape even after extensive practice, whereas shape naming was resistant to interference. To reconcile these findings with theoretical accounts of interference, reading may be conceptualized as involving visual-verbal associations akin to shape naming. An inherent or early-developing advantage for naming shapes may provide an evolutionary substrate for the invention and development of reading.

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## 1. Introduction

Stroop interference (Stroop, 1935) is commonly considered to be among the most familiar, most cited, and most investigated phenomena in all of cognitive psychology (MacLeod, 2005). It is well established that it takes longer to name the color in which a word is printed when the word means a different color (e.g. the word "red" printed in green ink). In contrast, the color a word is printed in makes no difference in reading the word. A complete explanation of this basic asymmetry remains elusive. MacLeod (1991) surveyed the landscape two decades ago and charted a list of challenges for theorists. A number of theoretical accounts have approached the topic from different angles, including automaticity (Cohen, Dunbar, & McClelland, 1990), attentional filtering (Phaf, Van der Heuden, & Hudson, 1990) or conflict monitoring (Botvinick, Braver, Barch, Carter, & Cohen, 2001) in connectionist networks; information theoretical considerations (Melara & Algom, 2003); and verification (Roelofs, 2003) or utility learning (Lovett, 2005) in goal-directed production systems.

All of these accounts, in one way or another, are concerned with the strong asymmetry observed between color naming and word reading, and between their relative interference and facilitation effects. Crucially, the source of the asymmetry in these approaches is experience-dependent. That is, reading interferes with color naming rather than vice versa due to the extensive history of reading compared to color naming, that is, greater practice in the word naming dimension (MacLeod, 1991, p. 182; MacLeod & MacDonald, 2000). Lovett (2005, p. 496) suggested that "utility" mediates the effects of practice, a distinction of consequence only when competing processes differ in task efficiency. In the "tectonic theory," dimensional imbalance arises from differences in long-term memory access efficiency resulting from differences in processing experiences (such as perceptual, linguistic, decisional, and response-related experiences with words or colors; Melara & Algom, 2003, p. 430).

When a structural asymmetry is posited, it is specific to the nature of reading having to do with direct associations between written and spoken word forms through verbal processes. In the model of Phaf et al. (1990), the asymmetry was introduced ad hoc, to

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account for the "privileged status" of inherent compatibility between written and spoken words (p. 310). Likewise, Roelofs (2003) posited an inherent privilege that is specific to written words, in that written word inputs are granted direct access not only to lemmata but also to the corresponding spoken word forms. Other kinds of inputs enjoy no such preferential treatment. According to this model, shape naming and color naming must be initially symmetric. Both are conceptually mediated, in the sense that the visual input must first activate the relevant concept (of the shape or color), which subsequently activates the corresponding lemma, which, in turn, activates the word form. Extensive practice may support the formation of direct links between visual stimuli (such as shapes or colors) and the corresponding naming responses, thus becoming "similar to reading aloud" (p. 117). Thus, in every current model of interference between two processing dimensions, practice is the crucial factor behind the dimensional imbalance that determines the interference.

A surprisingly small number of studies have examined the development or malleability of interference through practice. MacLeod (1998) found reduction of interference but no reverse interference (from incongruent color to word naming), despite 5 or 10 days of training on color naming, attesting to the robustness of the asymmetry. More recently, Protopapas, Vlahou, Moirou, and Ziaka (2014) trained adults and children on neutral color naming and color word reading, over three daily sessions. No training effects were observed in adults. For children, a reduction of interference was observed in color naming after reading practice. No effect on word reading was evident after either kind of practice, consistent with the aforementioned asymmetry between word reading and color naming.

Extending the effect domain beyond color word reading, Pritchatt (1968) trained participants to respond with nonsense syllables to colors in a paired-associate learning task. He then tested for interference in a color naming task involving naming color patches and naming the trained nonsense syllables printed in a color different from their paired associate. This procedure replicated the interference effect with the newly formed color "names" (Exp. 3, p. 356). Asymmetric interference effects arose in comparison to a condition in which participants learned the reverse associations, that is, responding with color names to nonsense syllables; however, the relative magnitude of the effects was not examined. Glaser and Dolt (1977, Exp. 2) trained participants to respond with nonsense syllables to colors and to color words, introducing an additional step of presumed association. This caused substantial and equal interference in both directions, eliminating any asymmetry. Unfortunately it is not known precisely how much each dimension was practiced, because participants were simply instructed to overlearn the dimensions within a week at their leisure. It is possible that highly unequal amounts of practice may have been required in the two dimensions.

In a related experiment, MacLeod and Dunbar (1988) trained participants to respond to unfamiliar shapes with familiar color names, in a visual-verbal paired associate learning task using color words. The resulting "shape naming" was vulnerable to interference from incongruent colors in the early stages of training but the asymmetry was eventually reversed: After 20 days of practice, color names for the shapes interfered with regular color naming, consistent with a practice-based account of interference, in which the novel shape-word pairings became sufficiently automatic to cause interference. However, the reverse association was not tested. That is, it is unknown whether practicing "color naming" of unfamiliar colors using familiar shape names might lead to a reversal of interference eventually affecting regular shape naming.

These findings indicate that novel paired-associate learning may lend itself to investigation of the development of Stroop interference. In particular we are interested in the origin of the asymmetry between word and color naming. If the asymmetry is related specifically to reading, as posited by certain models (Phaf et al., 1990; Roelofs, 2003), then it should not arise in the context of training that does not involve words. Moreover, if the asymmetry is caused simply by the different amount of practice in naming each dimension, then no asymmetry should arise between any two dimensions after equal amount of practice. Combining these two predictions to cover all current theories of Stroop interference, it follows that in any case no asymmetry should arise from equal amounts of practice in two dimensions that do not include written word forms. This is the hypothesis tested in the present study.

In contrast to expectations from theories of interference, findings in other domains suggest that different dimensions may not start on equal footing when it comes to naming. Specifically, an asymmetry between learning shape and color names can be found in lexical development. It is long established that names for colors are acquired by children slowly, much later and with more difficulty than names for common objects, both in normal language development and in experimental settings eliminating differential experience (Bornstein, 1985a, 1985b; Pitchford & Mullen, 2003). Young children seem to rely primarily on shape to extend word meanings (Keil, 2008). Accordingly, a "shape bias" in object name learning has been proposed, to account for the finding that infants and toddlers readily generalize verbal labels to artifacts with the same or similar shape, in contrast to alternatives matched in other dimensions such as color, size, texture, or material—though some of these dimensions come into play in certain domains such as food and animate entities (Colunga & Smith, 2005; Landau, Smith, & Jones, 1988). Although the precise source and nature of this bias remains contentious (Booth & Waxman, 2008; Colunga & Smith, 2008; Markson, Diesendruck, & Bloom, 2008; Samuelson & Horst, 2008; cf. Elman, 2008; Keil, 2008), the dominance of shape in constraining naming domains is undisputed. The pervasiveness and importance of this phenomenon is underscored by findings of a diminished shape bias in children with specific language impairment (Collisson, Grela, Spaulding, Rueckl, & Magnuson, 2015).

An asymmetry between color and shape naming has also been demonstrated in interference studies with children. Prevor and Diamond (2005) reported a predominant tendency toward object naming rather than color naming in children across the ages of 3½–6½ years. Children named the colors of abstract shapes faster than the colors of nameable objects. In the incongruently colored conditions, the presence of a nameable object interfered with color naming whereas no interference was observed in object naming. La Heij, Boelens, and Kuipers (2010) replicated the object interference effect in children, but they also found that it does not apply to adults, attributing the discrepancy to the development of inhibitory control. However, in those experiments there was no within-set conflicting response. That is, interfering object names were different from affected color names. In contrast, in the Stroop paradigm—as in our experiments below—competing color and word responses belong to the same set, resulting in increased interference (cf. "response set effects"; MacLeod, 1991; Roelofs, 2003).

In the present study we examine whether color naming and shape naming are initially symmetric, as posited by theories of interference, or asymmetric, consistent with the shape bias observed in lexical development. In the first two experiments that follow, participants were trained to respond with nonsense syllables to colors and shapes (Chinese characters in Experiment 1 and familiar geometrical shapes in Experiment 2). One group trained more on the colors and another trained more on the shapes, in precisely counterbalanced training schedules. The third experiment is a conceptual replication of MacLeod and Dunbar (1988), in which one group practiced shape naming with color words and another group practiced color naming with shape

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