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The effect of the color red on encoding and retrieval of declarative knowledge☆

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ABSTRACT

Studies on color psychology have demonstrated that the color red impairs cognitive performance in achievement situations. This study extends this line of research to the context of learning. One hundred and ninety students of a secondary school were instructed to memorize a short text (encoding phase). Subsequently, they were administered a knowledge test and a measure of cognitive load (retrieval phase). The experimental design manipulated the color (red versus gray) of the stimulus material during the encoding and the retrieval phase. For boys, repeated color exposure affected test performance more strongly than color presentation during a single phase. In contrast, for girls, a single color manipulation impaired knowledge retrieval, whereas repeated exposure to red had no effect. Descriptive analyses identified similar effects for cognitive load.

Colors are omnipresent in our daily lives, including the places where we study and take our exams. Although colors are often used for mere esthetic reasons, they carry psychological meaning and have notable behavioral implications (for a current review, see Elliot & Maier, 2014). In educational settings, recent research has shown that the color red impairs cognitive performance in challenging tasks (e.g., Elliot, Maier, Moller, Friedman, & Meinhardt, 2007; Gnambs, Appel, & Batinic, 2010; Ioan et al., 2007; Shi, Zhang, & Jiang, 2015). These results are based on the idea that red evokes an avoidance motivation that, in turn, hampers performance in tasks that require intelligent thinking, creativity, or both (Elliot et al., 2007; Maier, Elliot, & Lichtenfeld, 2008; Mehta & Zhu, 2009; Tanaka & Tokuno, 2011). Extending prior research in color psychology, the present study examined color effects for learning outcomes in the context of a regular school lesson which involved a color manipulation at the stage of knowledge encoding and at the stage of knowledge retrieval. Moreover, potential gender differences in the effects of red color on learning and the role of cognitive load as a mediator of the color effect were taken into account.

1. The color red and performance

Recent research has shown that red impedes performance in basic cognitive ability tasks (cf. Elliot & Maier, 2014). For example, when the participant number on an exam sheet was presented in red color (vs. green or black), participants performed worse in an anagram test. Moreover, participants performed worse in an intelligence subtest (analogies or number series) when an introductory test booklet sheet was colored red (vs. green or white, Elliot et al., 2007; see also Elliot, Payen, Brisswalter, Cury, & Thayer, 2011). Results further suggested that processes triggered by avoidance motivation (i.e., an initiation of behavior away from negative stimuli; Elliot, 2006), mediated this detrimental effect of red on cognitive performance. This assumption was supported in a subsequent series of experiments focusing on fluid intelligence measures (Maier et al., 2008). Although the effect of avoidance motivation induced by red color seems to depend on the specific task at hand—for example, red color facilitated performance on detail-oriented cognitive tasks such as proofreading (Mehta & Zhu, 2009)—most studies in the cognitive domain demonstrated poorer performance for respondents facing red (Elliot, Maier, Binser, Friedman, & Pekrun, 2009; Shi et al., 2015; Tanaka & Tokuno, 2011). Even simply reading the word 'red' resulted in lowered fluid intelligence test scores (Lichtenfeld, Maier, Elliot, & Pekrun, 2009).

Despite ample evidence of the negative influence of red color on various measures of cognitive performance, research on the effects of red color has neglected a fundamental component of cognitive functioning: learning. In contrast to the performance in cognitive ability tests,

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learning consists of the encoding of new information into memory and the retrieval of information at a later point of time. Information encoding and retrieval are two distinct processes (Rutherford, Markopoulos, Bruno, & Brady-Van den Bos, 2012). Research within the framework of environmental context-dependent memory (cf. Smith & Vela, 2001) highlighted that the nature of the context during the encoding phase and during the retrieval phase can interact: Memory performance was better when the environment during encoding and the environment during information retrieval were similar, as compared to instances in which the environment changed. In this sense, colors as salient perceptual cues of the environment may differentially affect learning and later retrieval processes, depending on whether environmental colors change or do not change between learning and retrieval phases. Thus, the effects of the repeated use of the color red may not readily extrapolate from previous research, which involved red color cues at only one point of time. The present study aimed to fill this empirical gap regarding the effects of repeated color exposure.

2. Gender differences in the influence of the color red on performance

Some of the previous studies found similar color effects for both genders (e.g., Maier et al., 2008; Mehta & Zhu, 2009), but others found a stronger effect of the color red on male than on female participants (Gnambs et al., 2010; Hill & Barton, 2005; Ioan et al., 2007; Shibasaki & Masataka, 2014). For example, Gnambs et al. (2010) showed that men (but not women) scored significantly lower on a web-based general knowledge test when parts of the survey page were colored red as compared to green. Two lines of reasoning hint at potential gender differences in the effects of the color red.

On the one hand, red acts as a sign of danger and a trigger of avoidance motivation in achievement situations (Maier et al., 2008). On average, women score higher on avoidance motivation than men (Carver & White, 1994), and they have been found to perceive more danger in achievement situations than men, who perceive more danger in situations of affiliation (Pollak & Gilligan, 1982). Thus, one may suggest that women are more sensitive to red color as a warning signal in achievement contexts and, hence, have a lower threshold for reacting with avoidance motivation. In partial support of this assumption, some results on the detrimental effect of the color red were based on exclusively or predominantly female samples (cf. Elliot et al., 2007, 2009; Shi et al., 2015).

On the other hand, in many Western societies reddish colors are associated with girls, and dark colors (e.g., brown, black, gray, and blue) are associated with boys (cf. Boyatzis & Varghese, 1994). In line with these dominant cultural schemes, many parents raise their children accordingly (Shakin, Shakin, & Sternglanz, 1985). Manufacturers of toys use gender-specific coloration (as can be impressively seen when googling images with the search terms “toys for girls”). Therefore, females likely associate many positive experiences with red and it may be a color with outstanding positive valence for them. Many objects colored red are desirable for girls (and women, e.g., a red rose or nail polish) and, hence, induce approach motivation (i.e., an impulse directed to go toward a positive goal; Elliot, 2006). In contrast to men, women are more likely to prefer red, purple, and pink (Cohen, 2013). Accordingly, Hurlbert and Ling (2007) found cross-cultural gender differences in participants' color preferences indicating some biological origin. Women favored reddish colors, men preferred blue and green. The preference for red color could reduce the red color effect, particularly when women are exposed repeatedly to this favored color. This assumption is supported by a recent study showing that the repeated presentation of red distorts time perception in men but not in women (Shibasaki & Masataka, 2014), indicating “a sex difference in the emotional valence of red” (p. 3).

Consequently, there are two arguments to expect gender differences in color effects on learning: there is evidence for gender differences in red-sensitive avoidance motivation as well as evidence for gender differences in the preference for red on the behavioral and biological level. This possible gender by color interaction might yield important practical implications for the field of learning with respect to gender-fair learning materials at school.

3. Study overview and predictions

All previous studies on color red realized one-shot designs in which the color manipulation either preceded a task or was applied during task processing (e.g., Elliot et al., 2007; Gnambs et al., 2010; Maier et al., 2008). Whereas one-shot designs are appropriate for the study of cognitive performance investigated in these studies, the context of learning requires a repeated measures design, since learning paradigms comprise two processes: learning and retrieval. Hence, in the present study, color was independently manipulated during the encoding and during the retrieval phase of learning. In this context, we assumed a gender-specific effect of the color red: males who show a lower preference for red color should perceive it as the common warning signal for danger in achievement contexts (cf. Elliot et al., 2007). Due to a potential gender effect in the emotional valence of red, seeing red should induce avoidance but not approach motivation in males (Shibasaki & Masataka, 2014). However, as males perceive less danger in achievement situations than females (Carver & White, 1994; Pollak & Gilligan, 1982) the effect of red should be smaller when presented only at one time, that is, either in the learning phase or in the retrieval phase. Consequently, a red color treatment during a learning phase as well as during a later retrieval phase should reduce males' performance more than color exposure exclusively during learning or retrieval.

H1. For boys, red color during the encoding and retrieval phase impairs test performance more strongly than a control condition with gray color or conditions with red presented only in one of the two phases.

For females—having a stronger preference for red—two competitive mechanisms should occur: on the one hand, like males, they should initially perceive red as the common signal for danger (Elliot et al., 2007), and because they perceive more danger in achievement situations in general, avoidance motivation should be triggered faster in comparison to males. This is the process that has apparently driven results of previous studies in which the majority of participants were females (e.g., Elliot et al., 2007; Shi et al., 2015). On the other hand, red should also evoke approach motivation among females when presented in the same context later once again. Because of the identical content of the tasks in the learning and retrieval phase, the same color presented twice contributes to a familiar learning context (e.g., Brinegar, Lehman, & Malmberg, 2013). This should facilitate the positive effect of red on approach motivation in females, that is, red should lose its initially impeding nature in the retrieval phase and approach motivation should be the dominant mechanism, due to the generally positive valence of red for females (cf. Shibasaki & Masataka, 2014). Consequently, we expect that the presentation of red during learning and later retrieval will result in no performance difference compared to a control condition in which gray is used.

H2. For girls, red color cues during the encoding and retrieval phase do not impair test performance as compared to a control condition with gray color.

Finally, several studies (e.g., Maier et al., 2008; Mehta & Zhu, 2009) have demonstrated that the detrimental effect of red color in performance settings is triggered by avoidance motivations. Avoidance motivation has several negative consequences, such as affective reactions (e.g., worries, self-doubts), a shift of attention toward potential threatening cues, and the initiation of various self-protecting