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Decline of the McCollough effect by orientation-specific post-adaptation exposure to achromatic gratings

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ABSTRACT

The McCollough effect is a contingent color after effect induced by adapting to colored gratings for several minutes. It has been demonstrated that a long-lasting adaptation effect such as the McCollough effect can be diminished by exposure to achromatic versions of the induction stimuli. However, the orientation specificity of this effect of post-adaptation exposure is not known. Here we report the findings from two experiments conducted to determine the influence of achromatic gratings and their orientation on the strength of the McCollough effect. After adaptation to the McCollough stimuli, participants were exposed to achromatic gratings or to one of two control conditions (either waiting in the dark or different-orientation achromatic gratings). Results suggest a significant decline of the McCollough effect after perceiving achromatic gratings in comparison to waiting in the dark or being exposed to different-orientation achromatic gratings. Thus, the effect of post-adaptation exposure to achromatic gratings is orientation specific.

1. Introduction

The McCollough effect (ME) is a contingent color after effect induced by adapting to colored gratings for several minutes (McCollough, 1965, 2000). For example, a horizontal grating may be paired with green, alternating with a vertical grating paired with magenta. Following this adaptation procedure, achromatic gratings of the same orientation will appear tinted with weakly saturated hues approximately complementary to those paired with each orientation during the induction process. In the example above, the gray portions of vertical gratings would appear slightly green and the gray portion of horizontal patterns would appear slightly pink. However, when the orientations of the gratings were rotated 45° from the adapted orientations, no color after effects were reported. Here we investigate whether a similar orientation specificity is observed for the decline in the McCollough effect induced by the post-adaptation exposure to achromatic gratings.

One of the most interesting aspects of the ME is its longevity, relative to the time it takes to build up of the effect. A recent study performed by Vul, Krizay, and MacLeod (2008) suggests two separable timescales of adaptation: a quick adaptation (supported by a short timescale) and a slow decay (supported by a long timescale). The 30-s (fast) timescale appears to be consistent with classic contrast adaptation dynamics. The "infinite" (slow) timescale is responsible for the long-lasting characteristic of the McCollough effect and it is presumably this permanent component that has been measured in classic studies of the persistence of the McCollough effect (ME). The interpretation of Vul, Krizay, and MacLeod (2008) of this "infinite" timescale is that the de-adapting stimuli are encountered very rare in the world. Hence, the longevity is a consequence of the lack of a de-adaptation opportunity.

Several studies in the past have examined how de-adaptation influences the decay characteristics of the ME (MacKay & MacKay, 1974; Skowbo et al., 1974; McLoughlin, 2005). Skowbo et al. (1974) demonstrated that a prolonged exposure to achromatic patterns similar in spatial composition to the induction stimuli causes the ME to decay unusually fast in comparison to other visual stimuli such as colored homogeneous fields, natural visual stimulation or complete darkness. These results were replicated in several studies with different control conditions (Skowbo, 1988; Skowbo & Clynes, 1977; Skowbo, Garrity, & Michaud, 1985; White & Graves, 1976). Surprisingly, none of these studies included the most stringent control condition of achromatic gratings with a different orientation than the induction stimuli. Thus, these studies cannot exclude the possibility that the decay of the ME is caused by the exposure to gratings per se, whether it is the same orientation as the adaptation stimuli or another orientation. Here we investigate this issue in two experiments in which we first replicate the basic result found by previous studies that post-adaptation exposure to gratings reduces the ME, and then test whether there is a differ-

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ence between same orientation gratings or opposite orientation gratings as post-adaptation stimuli.

2. General methods

2.1. Equipment and participants

We conducted both experiments at the University of Leuven (K.U. Leuven) with undergraduates and graduates. Sixteen participants (mean age = 23.62, standard deviation = 2.20; including 6 males) participated in the first experiment and 16 participants (mean age = 23.31, standard deviation = 1.45; including 4 males) participated in the second experiment. All participants were naïve to the purpose of the experiment and each participant participated in only one of the two experiments. We used a pc computer with Windows XP to run the experiment. To present the stimuli we used a gamma corrected monitor set to a resolution of 1024×768 at a refresh rate of 85 Hz. Participants carried out the task in a dark room for the entire duration of both experiments. The ethical committee of the Faculty of Psychology and Educational Sciences approved the procedures and we obtained written informed consent from the participants.

2.2. Testing procedure

We presented an adaptation stimulus for 5 s, followed by a 1 s fixation cross during the adaptation phase. The adaptation phase lasted 10 min. Afterwards, an 1 min rest period followed during which the participants waited in a dark room to avoid possible retinal after effects. We presented achromatic gratings for 750 ms and these were followed by a 250 ms fixation cross.

We used two grating orientation sets: cardinal (horizontal and vertical) and oblique (45° and 115°). The adaptation and achromatic gratings were 2.5 cycles/deg and subtended a total of 15° visual angle horizontally and 20° of visual angle vertically (Fig. 1). The adapting grating colors were always red and green with following CIE *xyY* color space coordinates: red (0.402, 0.233, 70) and green (0.318, 0.631, 70). The achromatic gratings were black (0.316, 0.419, 17.8) and gray (0.357, 0.148, 70) corresponding with the background. We counterbalanced the color-grating pairings (e.g. vertical with pink and horizontal with green) across participants. We separated the two gratings by a black bar located across the center of the screen and it subtended a total of 3° visual angle horizontally and 20° of visual angle vertically. The two gratings appeared adjacent to the black bar, either on the left or the right half of the gray background which was randomly chosen for each trial.

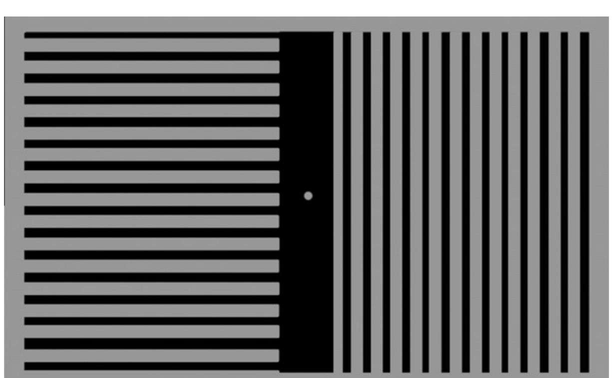

Fig. 1. An example of an achromatic grating with the cardinal grating orientation set.

We opted to randomly select the phase of each adaptation or test grating in every individual trial.

The post-adaptation phase followed the adaptation phase, in which participants were exposed to a visual stimulation (waiting in the dark or gratings) (Fig. 2). After each adaptation post-adaptation (APA) sequence participants matched the color of the after effect. Participants matched the colors by adjusting RGB values of a circle below a test grating by pressing one of three buttons (changing the color dimension (red/green/blue); less color in current color dimension; and more color in current color dimension). When the color of the circle matched the color of the after effect in the test grating participants pressed the stop button. We trained the participants in the color matching task before the experiments were started. In order to minimize carry-over between two adaptation periods, we alternated the orientation set (cardinal or oblique) between successive adaptation periods. All conditions (orientation-color pairing, oblique or cardinal adaptation and/or post-adaptation and whether the wait/opposite grating condition occurred in the first or second run) were counterbalanced across participants.

3. Experiment 1

The goal of Experiment 1 was to test whether intervening stimulation with gratings influences the strength and the duration of the ME. Two different post-adaptation conditions were presented to each participant and each condition was followed by a matching task.

3.1. Methods

We presented two adaptation periods and each adaptation period was followed by a wait condition (a gray screen was presented) or a same-orientation achromatic grating condition (test gratings with the same orientation as the adaptation stimuli; e.g. cardinal chromatic gratings as adaptation stimuli and cardinal achromatic gratings as post-adaptation stimuli) (Fig. 2). Half of the participants were exposed to the short version of the task, namely an post-adaptation phase of 2 min. The post-adaptation phase of the other half of the participants lasted for 5 min. A matching task (for more details, see Section 2) followed after each APA sequence.

3.2. Results

The RGB values of the matched colors of the participants were transformed to CIE *xyY* values. The Euclidian distance between the two matched after effect colors was calculated in the CIE *xyY* space for each condition and represented the after effect strength. We analyzed the data as a repeated-measures ANOVA with the duration of the post-adaptation conditions as between-participant factor and as within-participant factor the wait versus same-orientation achromatic grating condition (Fig. 3). There was a significant main effect of the post-adaptation condition ($F(1,14) = 10.01$, $p = 0.007$), which showed that the after effect strength was smaller when same-orientation achromatic gratings were presented after adaptation in comparison to the wait condition. There was no significant main effect of duration ($F(1,14) = 0.03$, $p = 0.871$) and no significant interaction effect of the duration with the post-adaptation condition ($F(1,14) = 2.32$, $p = 0.15$).

3.3. Discussion

The results of Experiment 1 show that the decay of the ME is accelerated when exposing participants to achromatic gratings that contain the same orientation as the adaptation stimuli of the ME, in comparison to having minimal visual stimulation after