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About individual differences in vision

Lukasz Grzeczkowski [a,*], Aaron M. Clarke [a,b], Gregory Francis [a,c], Fred W. Mast [d], Michael H. Herzog [a]

[a] Laboratory of Psychophysics, Brain Mind Institute, École Polytechnique Fédérale de Lausanne (EPFL), Switzerland
[b] Bilkent University, Ankara, Turkey
[c] Purdue University, West Lafayette, IN, USA
[d] Department of Psychology, University of Bern, Switzerland

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ABSTRACT

In cognition, audition, and somatosensation, performance strongly correlates between different paradigms, which suggests the existence of common factors. In contrast, visual performance in seemingly very similar tasks, such as visual and bisection acuity, are hardly related, i.e., pairwise correlations between performance levels are low even though test-retest reliability is high. Here we show similar results for visual illusions. Consistent with previous findings, we found significant correlations between the illusion magnitude of the Ebbinghaus and Ponzo illusions, but this relationship was the only significant correlation out of 15 further comparisons. Similarly, we found a significant link for the Ponzo illusion with both mental imagery and cognitive disorganization. However, most other correlations between illusions and personality were not significant. The findings suggest that vision is highly specific, i.e., there is no common factor. While this proposal does not exclude strong and stable associations between certain illusions and between certain illusions and personality traits, these associations seem to be the exception rather than the rule.

1. Introduction

Common factors are ubiquitous in human life. For example, performance in mathematics is strongly correlated with performance in physics (Blumenthal, 1961; Cohen, 1978; Hudson & Rottmann, 1981). Similarly, performance in many cognitive tasks is strongly correlated (Johnson, Bouchard, Krueger, McGue, & Gottesman, 2004; Johnson, te Nijenhuis, & Bouchard, 2008), which is often taken as evidence for a high-level general intelligence factor, commonly known as Spearmans's *g* (Jensen, 1998).

In perception, there are strong relationships between touch and audition, likely because both senses share common genetic factors related to mechanoreception (Frenzel et al., 2012). In visual perception, there is a long history of relating visual performance or susceptibility to illusions to personality, intelligence, or cognition and other visual functions (Coren & Porac, 1987; Galton, 1883; Gregory, 2004; Jensen, 2002; Piaget, 1969; Roff, 1953; Spearman, 1904; Thurstone, 1938, 1944).

With a battery of forty-four tests, Thurstone (1944) found that susceptibility to geometric illusions is one out of eleven visual factors. Switch rates in the Necker cube strongly correlate with IQ and age in children (Holt & Matson, 1974). In a large-scale study with 490 observers, visual abilities such as detecting a simple figure in a more complex one correlated with the strength of spatial illusions (Coren & Porac, 1987). In addition, primary visual cortex size correlated negatively with the illusion magnitude in the Ebbinghaus, Ponzo and tilt illusions (Schwarzkopf & Rees, 2013; Schwarzkopf, Song, & Rees, 2011; Song, Schwarzkopf, & Rees, 2013).

Surprisingly, studies investigating basic visual paradigms, such as Vernier acuity or Gabor detection, found only weak or non-significant correlations between different paradigms (Bosten & Mollon, 2010; Cappe, Clarke, Mohr, & Herzog, 2014; Peterzell, Werner, & Kaplan, 1995; Webster & MacLeod, 1988, but see Rabideau, 1955). Peterzell and Teller (1996) found that contrast sensitivity for gratings with frequencies lower than 1 cycle/degree are strongly correlated with each other. Surprisingly, sensitivity for these gratings is very weakly correlated to the sensitivity of gratings with frequencies higher than 1 cycle/deg (see also Billock & Harding, 1996; Peterzell, Chang, & Teller, 2000; Peterzell & Teller, 2000; Peterzell, Werner, & Kaplan, 1993; Peterzell et al., 1995; Simpson & McFadden, 2005). Bosten and Mollon (2010) measured the susceptibility to simultaneous contrast perception of luminance, color, luminance contrast, color contrast, orientation, spatial frequency, motion and numerosity and found only a few significant

* Corresponding author.
E-mail address: lukasz.grzeczkowski@epfl.ch (L. Grzeczkowski).

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correlations with 101 observers. They concluded that there is "*no noteworthy general trait of susceptibility*" to contrast perception. These null results are not due to low test re-test reliability or low statistical power.

Here, we re-investigated the question of common factors for visual illusions with two experiments. First, we investigated how strongly the magnitudes of six visual illusions correlate with each other. If there is a common factor for visual illusions, a person strongly susceptible to one visual illusion should also be strongly susceptible to other illusions, and the magnitudes of those illusions should correlate. To the contrary, we found that most pairwise correlations were non-significant, except for a significant association between the Ebbinghaus and Ponzo illusion. In a second experiment, we investigated to what extent mental imagery and four classic personality factors correlate with illusion strength. We found some stable and significant associations, for example between mental imagery and the magnitude of the Ponzo illusion. However, the majority of comparisons were not significant. Thus, whereas there are stable associations between certain factors, there seems to be no general factor for illusions and no general association between personality and illusion strength.

2. Experiment 1

2.1. Methods

2.1.1. Participants

Participants were 144 visitors (69 females) of the SwissTech Convention Center (Lausanne, Switzerland) participating in its inauguration ceremony. Participant ages ranged from 6 to 81 years old (median = 22). Adults signed informed consent forms. Non-adult participants' consent forms were signed by their parents. Participants were not paid for their participation. Procedures were conducted in accordance with the Declaration of Helsinki and were approved by the local ethics committee.

2.1.2. Apparatus

Stimuli were shown on BenQ XL2420T monitors driven by PC computers using Matlab (R2013b, 64 bits) and the Psychophysics toolbox (Brainard, 1997; Pelli, 1997; version 3.1, 64 bits) at 1920 × 1080 pixels resolution and at a 60 Hz refresh rate. Participants sat ≈ 60 cm from the screen and adjusted stimuli with a Logitech LS1 computer mouse. Prior to the experiments, the monitors' color look-up tables were linearized by calibrating with a Minolta LS-100 luminance meter. The experiment was conducted in a provisory experimental room especially built for this experiment at the inauguration event.

2.1.3. Stimuli

For each observer, the strength of six visual illusions was tested: Ebbinghaus illusion (EB), Müller-Lyer illusion (ML), simultaneous contrast illusion (SC), Ponzo "hallway" illusion (PZh), White illusion (WH), and tilt (TT) illusion (Fig. 1). For each illusion, we used the method of adjustment, where participants compared a reference stimulus with a second stimulus that they adjusted to match the reference by moving the computer mouse on its horizontal axis. For the Ebbinghaus, Müller-Lyer and tilt illusion, the center of the reference stimulus was 12.5 degrees to the left whereas the center of the adjustable stimulus was at 12.5 degrees to the right from the screen's center (Fig. 1).

In the Ebbinghaus illusion (EB), the reference was a white disk that was 3 degrees in diameter, surrounded by sixteen smaller yellow disks (inducers), 0.75 degrees of diameter each. The distance between the centers of the reference disk and the small inducers was 2.5 degrees. Large inducers, surrounding the adjustable disk were 6 degrees in diameter. The distance between the center of the adjustable disk and the center of each large inducer was 7.5 degrees. At the beginning of each trial, the adjustable disk appeared with a random size in the range of 0.0 to 9.2 degrees in diameter. Both the luminance of the yellow surrounding disks and the white central disks was ≈ 260 cd/m^2. The background luminance was ≈ 1 cd/m^2.

In the Müller-Lyer illusion (ML), the length of the reference line was 8 degrees and it was always presented with inward-pointing arrows. The lines composing the arrows were 1.5 degrees long. The adjustable line was always presented with outward-pointing arrows and its starting length varied randomly between 0 and 24 degrees. The line's luminance was ≈260 cd/m^2.

In the simultaneous contrast illusion (SC), the reference and the adjustable stimuli were small squares with a side-length of 4 degrees placed at 6 degrees to the left and right of the screen center, respectively. The luminance of the reference square was ≈66 cd/m^2. These small squares were embedded in bigger, 12 degree squares. The luminance of the big square placed on the left was ≈40 cd/m^2 and ≈140 cd/m^2 for the one on the right.

In the Ponzo "hallway" illusion (PZh), the diameter of the reference disk was 2.4 degrees. It was located in the top-right hand corner, with a center-to-center distance of 22.2 degrees from the screen's midpoint. The adjustable disk appeared in the lower-left hand corner, 16.6 degrees from the screen's center. The luminance of both disks was ≈40 cd/m^2. During the adjustment, the lowest point of the adjustable disk was fixed while its center moved up. This created the impression that the disk was anchored to the image background. The background image was a 1920 × 1080 pixel resolution grayscale picture of a hallway at the EPFL campus.

In the White illusion (WH), the background was composed of alternating dark (≈1 cd/m^2) and light (≈221 cd/m^2) horizontal, 2.7 degree wide stripes. The gray reference rectangles on the left were 2.7 degrees tall and 5.5 degrees wide. They were presented on light bands and their luminance was ≈33 cd/m^2. The adjustable rectangles appearing on the right lay on dark bands and were the same size as their reference counterparts. All rectangles were at 2.5 degrees from the screen's vertical meridian. During adjustments, the rightward rectangles changed gradually in luminance, with a starting luminance chosen randomly at the beginning of each trial from between ≈0 and 260 cd/m^2.

In the tilt illusion (TT), the reference and the adjustable stimuli were disks with a diameter of 6 degrees, each containing a 0.5 cycles/deg full contrast grating texture. The reference disk was tilted 33 degrees towards the clockwise direction from vertical and was embedded in a larger disk (20 degrees in diameter) with the same grating frequency but tilted 36 degrees towards the counter-clockwise direction. The background luminance was ≈33 cd/m^2. The adjustable disk appeared with a random orientation between 0 and 360 degrees.

2.1.4. Procedure

The experimenters first explained the task to the participants and showed each illusion once on the computer screen. The starting value of the size, length, luminance or the orientation of the adjustable stimulus was randomly chosen by the computer (cf. stimuli section). Each participant performed two trials per illusion without any time restrictions. All participants adjusted the illusions in the same order: EB, ML, SC, PZh, WH and TT. The experimenters were continuously present to answer any questions. Participants were asked to make their adjustments relying on their perception and to ignore any prior knowledge they may have had of visual illusions. At the end, participants could see their own results on the computer screen and were debriefed by the experimenter.

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