No Stopping and No Slowing: Removing Visual Attention with No Effect on Reversals of Phenomenal Appearance

Alexander Pastukhov, Victoria Vonau, and Jochen Braun

Cognitive biology, Otto-von-Guericke Universität, Leipziger Strasse 44 / Haus 91, 39120 Magdeburg, Germany
{Alexander.Pastukhov,Jochen.Braun}@ovgu.de,
Victoria.Vonau@st.ovgu.de,
http://kobi.nat.uni-magdeburg.de

Abstract. We investigated whether visual selective attention contributes to the reversals of phenomenal appearance that characterize multi-stable displays. We employed a rotating-ring display that reverses appearance only at certain phases of its rotation (i.e., when in full-frontal view). During this critical window of time, observers were required to perform a shape discrimination task, thus diverting attention from the rotating ring. Our results showed that perceptual reversals were neither stopped nor slowed by this manipulation. In contrast, interrupting the display during the critical times increased the frequency of perceptual alternations significantly. Our results go beyond earlier findings that sustained withdrawal of attention slows, but does not stop, perceptual reversals. Accordingly, the available evidence strongly suggests that visual selective attention plays no causal role in multi-stable perception.

Keywords: multi-stable perception, attention.

1 Introduction

When faced with ambiguous input, the visual system switches spontaneously between alternative interpretations. Although first scientific study of multi-stable perception was performed nearly two centuries ago [1], the mechanisms behind phenomenal alternations are still not fully understood. One theory, which was the first theory to have been put forward historically and which retains many adherents to this day, is that reversals of phenomenal appearance simply reflect shifts of visual selective attention [2,3]. Indeed, considerable evidence has accumulated over the years that both endogenous [4,5] and exogenous [6,7] manipulations of visual attention profoundly modulate the dynamics of multi-stable appearance. In addition, studies with functional imaging and neurophysiological techniques find consistently that reversals of phenomenal appearance are accompanied by activity in parietal and frontal cortical areas that are associated with visual attention and working memory (for a review, see [8]). However, it seems equally possible that visual attention triggers reversals or that reversals attract attention, so that the causal relation between attention and reversals remains unclear.

K. Diamantaras, W. Duch, L.S. Iliadis (Eds.): ICANN 2010, Part III, LNCS 6354, pp. 510–515, 2010.

Several studies have addressed this issue with dual-task paradigms, requiring observers to attend to a demanding discrimination task while also reporting on the phenomenal appearance of a multi-stable display [9,10,11]. Such a sustained and partial withdrawal of attention from multi-stable display significantly slows the pace of phenomenal reversals but fails to eliminate them. In fact, withdrawing attention has a similar effect as reducing stimulus intensity [10,11]. Other studies have attempted to withdraw attention completely from multi-stable displays by requiring observers to report only (or mostly) on the attention-engaging task. To monitor phenomenal a ppearance, these studies either relied on occasional observer reports [11] or on physiological correlates of the dominant percept such as eye movements [12] or EEG modulations [13]. The former two studies found that, in the absence of visual attention, phenomenal reversals continued, while the latter study seems to suggest that reversals may cease altogether.

To further investigate the causal role of visual attention in multi-stable perception, we have devised a modified version of the kinetic-depth display. The phenomenal appearance (rotation in depth) of this display reverses almost exclusively at a particular phase of the rotation, specifically, when the stimulus is in full-frontal view. To document this, we performed a control experiment in which observers reported phenomenal reversals together with the position of a "indicator dot" a the moment of reversal. (The "indicator dot" revolved around the display like the second hand of an analog clock.) All subjects reported reversals to occur shortly after the rotating ring passed the 0° ("full-frontal") orientation (Fig. 1A, mean switch time 29±5 ms). 98% of switches occurred within ±150 ms of 0° orientation. Taking decisional bias into account [14], it seems likely that the vast majority of reversals occurred within this critical window of time.

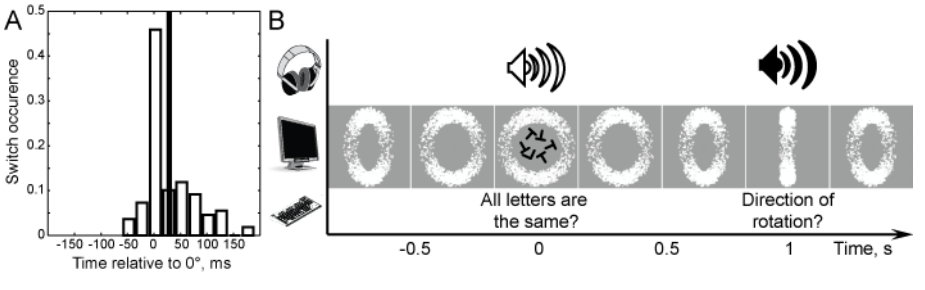

Fig. 1. A) Distribution of the reported switch times relative to the 0° (full-frontal view) orientation of the ring (time 0). Solid line shows mean of the distribution. B) Schematic procedure of the experiment. An ambiguously rotating ring was presented continuously but observers were prompted by an auditory signal (top row, filled icon) to report the direction of rotation only once a second. An attention-demanding letters task was presented for 300 ms and observers were prompted by an auditory single (top row, open icon) to report whether or not all letters were identical. For single task conditions observers were prompted to report only on one task.

In contrast with previous studies, which kept sustained attention on the central task for the entire duration of the block, we engaged attention only intermittently, specifically, for 300 ms around the 0° orientation ([-150...150 ms], 15% of total rotation time, see Fig. 1B). If visual attention is required to trigger a phenomenal reversal,

then withdrawing it from the rotating ring during the critical windows of time should stabilize phenomenal appearance and reduce the number of reversals. On the other hand, if withdrawing attention modulates merely the effective contrast of the display, we would expect at most a minor (<10%) decrease of the reversal rate [11].

2 Results

To ensure that all attention was directed away from the rotating ring, we have used a letter discrimination task, which has been shown to be highly attention demanding [15,16]. Observers were prompted by an auditory signal to respond whether all letters in the array were the same (Fig. 2B). They were also prompted, by a different tone, to respond on the ring's direction of rotation then ring was around 90° orientation. This ensured that observers payed attention exclusively to one task at a time, rather than splitting attention. In single task conditions observers responded to one of the tasks, while in the dual task situation they responded to each task in turn.

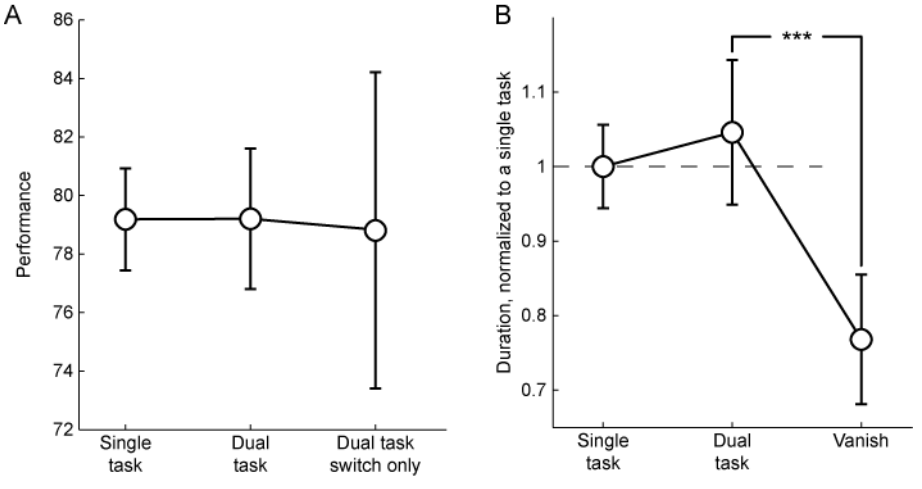

Fig. 2. Results. A) Central task average block performance for single and dual tasks, and average performance only during trials with a reported perceptual switch (dual task condition only, mean ±95% confidence interval). B) Mean dominance duration for *single task*, *dual task* and *vanish* condition. Durations are normalized to the mean dominance duration during single task condition of the session.

Observer's performance on the central task shows that they paid full attention to the central task in the dual task condition (Fig. 2A). Critically, there is no evidence that switches occurred only when observers failed to focus their attention on letters: their performance on trials with reported switches is not significantly different from their single task performance (binomial distribution, p= 0.93).

In contrast with previous studies, which observed slowing down of perceptual alternations if attention was withdrawn for the entire block duration, we find no significant increase in mean dominance duration during the dual task condition (see Fig. 2,

increase of 4.3%, Wilcoxon ranksum test, p= 0.16). We have also examined whether absence of attention on multi-stable displays is equivalent to its physical absence. In a control condition (*vanish*) rotating ring was removed from the screen during the central task target array presentation. Unlike withdrawal of attention, physical absence caused a significant increase of the alternation rate: mean dominance duration was smaller by 21% compared to the single task (Wilcoxon ranksum test $p<0.001$ then comparing with both single and dual task conditions).

3 Discussion

In the present study, we have examined the effect of withdrawing attention during the critical windows of time in which an ambiguously rotating ring may reverse its phenomenal appearance. Unlike previous studies, which found that sustained withdrawal of attention slows down the pace of phenomenal reversals, we observed that the intermittent withdrawal of attention had only a minor and non-significant effect on multi-stable dynamics (4.3% fewer reversals). This essentially negative result was obtained in spite of the well-documented effectiveness of the attention-engaging task [15,16]. This marginal and non-significant reduction in the number of reversals is consistent with the idea that withdrawing attention merely reduces the effective contrast of the display. On the basis of previous results [11], we estimated that a reduction of effective contrast should decrease the number of reversals by than 10%. A physical interruption of the stimulus produces a very different effect and increases the number of reversals by 21%, consistent with previous observations [17].

In a recent preliminary report [13], Zhang and colleagues employed frequency-tagging to monitor the phenomenal appearance of a multi-stable display by way of evoked scalp-potentials (EEG). They report that, when visual attention was withdrawn from the display, the frequency-tagging failed and that it was no longer possible to establish a dominant percept. From this the authors infer that neither percept dominated phenomenal appearance and that perceptual reversals ceased. However, other interpretations are possible as well. For example, withdrawing attention may have reduced effective contrast (and the amplitude of scalp potentials) to the point that phenomenal appearance could no longer be monitored in this way. Alternatively, as mentioned above, attention acts as an "effective contrast", boosting strength of the underlying neural responses [18,19]. Its withdrawal would decrease response amplitudes, particularly in the presence of a central task [20]. This reduction could render the display simply too weak to induce binocular rivalry, which is well known to require medium to high contrast [21]. Yet another possibility is that the flickering presentation required for frequency modulation could have rendered the display more prone to fusion. Accordingly, it remains to be seen whether this intriguing finding with an exotic display [13] can be generalized to more prototypical multi-stable situations.

We find that withdrawing attention intermittently during the time of phenomenal reversals has essentially no effect on the time course of multi-stable perception. This observation confirms and extends the conclusion of several earlier studies, which suggest that attention merely modulates the effective contrast of the stimulus without taking any causal part in perceptual reversals. We concluded that perceptual reversals are spontaneous and do not require prompting by visual attention.

4 Methods

Three participants (including second author) took part in the experiment. Procedures were approved by the medical ethics board of the University of Magdeburg and informed consent was obtained from all observers. Stimuli were displayed on a 21" CRT screen: 1600x1200 pixels, 100 Hz refresh rate, viewing distance was 70 cm.

Ring stimulus (diameter 12.5°, rotation speed 0.25Hz) consisted an orthographic projection of 2000 dots (diameter 0.2°) on the surface of the ring. Observers were prompted by a low frequency tone auditory signal (200 ms before ring reached position then it is orthogonal to the viewer) to report with a right hand its direction of rotation (left, right or unclear). Letter task consisted of an array of randomly rotated letters ('T' or 'L', size: 2°), presented for 300 ms (starting time 150 ms before the ring reached position when it is 'flat' for the viewer) around the fixation (eccentricity 8.5°). Target array was immediately followed by a mask, consisting of the same number of randomly rotated letters 'F' (200 ms). Number of letters was manipulated to ensure ~80% performance in a single task *letters* condition. Observers were prompted to report with a left hand whether odd item was present by a high frequency tone (200 ms before the target array onset). Visual stimulation was identical, but observers were prompted to report only rotation, only letter task or both intermittently. During *vanish* condition ring stimulus was absent during letter task target arrays presentation (300 ms). In control experiment conducted to establish time of the switch, observers viewed a continuously rotating ring with additional "indicator dot" revolving around the display like the second hand of an analog clock [14]. Observers were instructed to report perceptual switch by pressing 'space' button, while memorizing position of the indicator dot. After that they have manually adjusted its location to match its location at the time of the switch.

References

[1] Wheatstone, C.: Contributions to the physiology of vision–part the first. on some remarkable, and hitherto unobserved, phenomena of binocular vision. Philosophical Transactions of the Royal Society of London 128, 371–394 (1838)

[2] von Helmholtz, H.: Treatise on Physiological Optics, vol. 3. The Optical Society of America, Birmingham (1866)

[3] Leopold, D.A., Logothetis, N.K.: Multistable phenomena: changing views in perception. Trends. Cogn. Sci. 3, 254–264 (1999)

[4] Meng, M., Tong, F.: Can attention selectively bias bistable perception? Differences between binocular rivalry and ambiguous figures. Journal of Vision 4, 539–551 (2004)

[5] van Ee, R., van Dam, L.C., Brouwer, G.J.: Voluntary control and the dynamics of perceptual bi-stability. Vision Res. 45, 41–55 (2005)

[6] Chong, S.C., Tadin, D., Blake, R.: Endogenous attention prolongs dominance durations in binocular rivalry. Journal of Vision 5, 1004–1012 (2005)

[7] Mitchell, J.F., Stoner, G.R., Reynolds, J.H.: Object-based attention determines dominance in binocular rivalry. Nature 429, 410–413 (2004)

[8] Sterzer, P., Kleinschmidt, A., Rees, G.: The neural bases of multistable perception. Trends in Cognitive Sciences 13, 310–318 (2009)

[9] Reisberg, D., O'Shaughnessy, M.: Diverting subjects' concentration slows figural reversals. Perception 13, 461–468 (1984)
[10] Paffen, C.L., Alais, D., Verstraten, F.A.: Attention speeds binocular rivalry. Psychological Science: a Journal of the American Psychological Society, APS 17, 752–756 (2006)
[11] Pastukhov, A., Braun, J.: Perceptual reversals need no prompting by attention. Journal of Vision 7, 5 (2007)
[12] Leopold, D.A., Fitzgibbons, J.C., Logothetis, N.K.: The Role of Attention in Binocular Rivalry as Revealed through Optokinetic Nystagmus, pp. 1–17 (1995)
[13] Zhang, P., Engel, S., Rios, C., He, B., He, S.: Binocular rivalry requires visual attention: Evidence from EEG. Journal of Vision 9, 291 (2009)
[14] Joordens, S.: When Timing the Mind One Should Also Mind the Timing: Biases in the Measurement of Voluntary Actions. Consciousness and Cognition 11, 231–240 (2002)
[15] Lee, D.K., Koch, C., Braun, J.: Attentional capacity is undifferentiated: concurrent discrimination of form, color, and motion. Percept. Psychophys. 61, 1241–1255 (1999)
[16] Pastukhov, A., Fischer, L., Braun, J.: Visual attention is a single, integrated resource. Vision Research 49, 1166–1173 (2009)
[17] Orbach, J., Ehrlich, D., Heath, H.A.: Reversibility of the Necker cube. I. An examination of the concept of satiation of orientation. Perceptual and Motor Skills 17, 439–458 (1963)
[18] Boynton, G.M.: Attention and visual perception. Current Opinion in Neurobiology 15, 465–469 (2005)
[19] Reynolds, J.H., Chelazzi, L.: Attentional modulation of visual processing. Annual Review of Neuroscience 27, 611–647 (2004)
[20] Serences, J.T., Yantis, S., Culberson, A., Awh, E.: Preparatory activity in visual cortex indexes distractor suppression during covert spatial orienting. Journal of Neurophysiology 92, 3538–3545 (2004)
[21] Liu, L., Tyler, C.W., Schor, C.M.: Failure of rivalry at low contrast: evidence of a suprathreshold binocular summation process. Vision Research 32, 1471–1479 (1992)