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Top-Down Influences to Multistable Perception: Evidence from Temporal Dynamics

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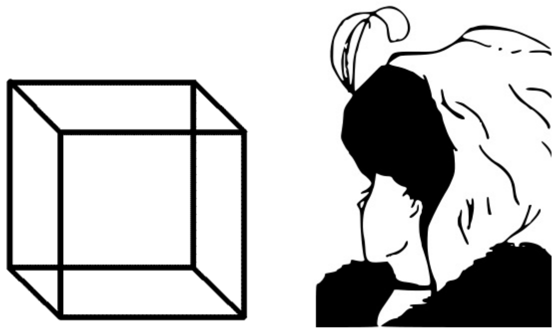
***Abstract*—**We have studied the temporal characteristics of bistable perception of the stimuli of two types: one involves alterations in a perceived depth and another one has an ambiguous content. We used the Necker lattice and lines of shadowed circles ambiguously perceived either as spheres or holes as stimuli of the first type. The Winson figure (the Eskimo/Indian picture) was a stimulus of the second type. We have analyzed how often the reversals occurred (reversal rate) and for how long each of the two interpretations, or percepts, was observed during one presentation (stability durations). For all three ambiguous images the reversal rate and the stability durations had similar values, which provide another evidence for a significant role of top-down processes in multistable perception.

***Keywords*—**Multistable perception, perceived depth, reversal rate, top-down processes.

I. Introduction

When we observe certain visual patterns, such as Necker cube (Fig. 1 A) or the Boring figure (Boring's Young woman/Old woman illusion, Fig. 1 B), our perceptual system is unstable and alternates spontaneously between two or more possible interpretations. Such multistability in perception can arise from a number of stimulus types, involving alterations in a perceived depth of a pattern or figure-ground organization. This phenomenon has been used largely in the visual sciences for investigating mechanisms of perceptual organization. Studies of multistable perception have been carried out for nearly 200 years and explanations followed two main traditions: the bottom-up (or sensory) and the top-down (or cognitive) explanatory approaches [1]. The bottom-up approach assumes that perceptual reversals arise from processes occurring in early visual areas [2]-[4]. The top-down approach assumes perceptual reversals as the result from active high-level (cognitive) processes like attention, decision-making and learning [5]-[7]. J. Kornmeier [1] lists some key findings supporting this approach: (1) Although the bottom-up approach implies regular oscillations between the two interpretations, the durations of successive intervals of transiently stable percepts (stability durations or "dwell times") are unpredictable and show characteristics of a stochastic process (e.g., fit to gamma distribution). According to [6] this is a signature of high-level exploratory behavior. (2) Perceptual reversals are very rare or even absent, when observers do not know that alternative interpretational possibilities exist, a finding hard to reconcile with fully automatic adaptation processes. Further, the rate of reversals can be modulated volitionally, although they cannot be prevented totally [8]. Another argument supporting this hypothesis could be the similarity of temporal dynamics of the multistable perception of stimuli where reversals are caused by different image features.



A B

Fig. 1 Examples of ambiguous images: A) Necker cube; B) Boring's Young woman/Old woman figure

II. Methods

A. Participants

Eleven female and seven male participants aged 21 to 40 with normal or corrected visual acuity took part in the experiment. All participants gave their informed written consent. The study was performed in accordance with the ethical standards of the Declaration of Helsinki.

B. Stimuli

The stimuli were three ambiguous images: the Necker lattice, designed by [9] (Fig. 2), five lines of shadowed circles ambiguously perceived either as spheres or cavities (holes) (Fig. 3) and the Winson figure (the Eskimo/Indian picture) (Fig. 4).

The Necker lattice, as well as the Necker cube, is considered to be a perspective reversing figure, which is characterized by the ambiguity of a two dimensional drawing with respect to its three-dimensional interpretation. The shadowed circles could be referred to the same category, though in this image its three-dimensional interpretation is based on the shading but not the perspective, as it is in case with the Necker cube. The Winson figure belongs to the

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content reversal category as its content may have two different interpretations.

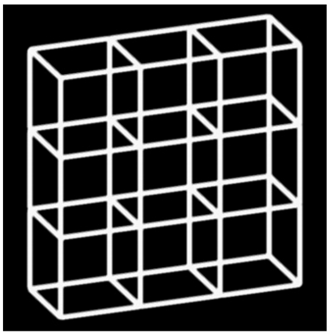

Fig. 2 Necker lattice

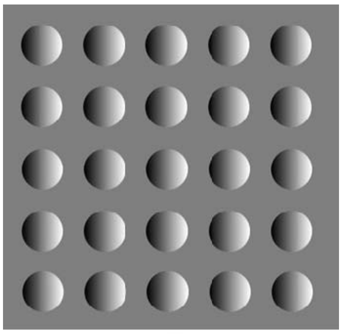

Fig. 3 Ambiguous shadowed circles

Fig. 4 Winson figure

A. Procedure

Stimuli were presented on the Iiama monitor with a frame rate of 103 Hz. Stimulus vertical size was 4.5°. A small cross in the center of the screen served as a fixation target.

The observers were sitting in front of the screen; the distance to the screen was 1.65 m. No head fixation was used. All observers were viewing the stimuli binocularly.

Each participant took part in one experimental trial, which included five one-minute presentations of each stimulus. Before experimental trial all participants were shown all three images to see perceptual reversals. Participants were instructed to press one of the two keys to indicate the moments of reversals. There was a short training session to make sure the participants understood the task and could see the two alternative variants of each image.

B. Data Analysis

For each ambiguous image we calculated the average number of perceptual reversals per minute (reversal rate) and the periods of stable perception (stability durations), that is for how long each of the two interpretations, or percepts, was observed during one presentation. For data comparison we used Mann-Whitney U-test, Wilcoxon single-rank test and Friedman test.

III. Results and Discussion

A. Reversibility

All 18 participants reported the reversals of the Necker lattice. Two observers had difficulty with reporting reversals of the Winson figure; they perceived its reversals but said that the alternative percepts were switching so fast that they couldn't catch the moments of the reversals.

Though most observers saw the reversals of the shadowed circles, four out of 18 people perceived this image unambiguously only as convex hemispheres but not as concave ones. We averaged the number of reversals of the Necker lattice and the Winson figure across the group of these four people (Group 2) and across the group of the rest 14 observers (Group 1). The number of reversals (reversal rate) for the two groups didn't differ significantly but in Group 2 its value showed a tendency to be less than in Group 1 for the both images analyzed (Fig. 5). That is those who couldn't see the reversals of the shadowed circles appeared to be slightly slower at reversing the other two images.

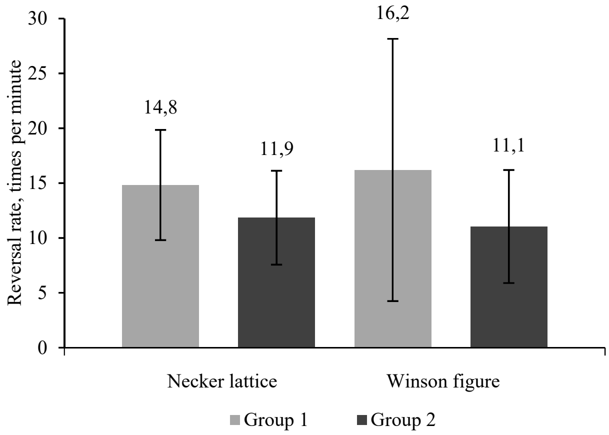

Fig. 5 Reversal rates of the two ambiguous images for the two groups (for details see text above). Error bars represent SD values

There are several studies discussing the relation between personal traits and bistable perception. For example, creativity was shown to correlate with the reversal rate [10], [11]. The authors demonstrated that those who rated themselves as more creative, original and visually oriented (compared to the rest of the group) reversed significantly more often. These findings were supported by [12], which showed that participants that rated high in an original thinking test also had high reversal rates [13].

Though in our study inter-individual differences in reversal rate are not significant and can be discussed only as a tendency, the results of a number of previous studies demonstrating the relation between bistable perception of the Necker cube and personality underscore the top-down component of the reversal process.

B. Reversal rate

The results of statistical analysis demonstrated that reversal rates for all three stimuli, averaged across the whole group of participants, didn't differ significantly (Fig. 6). The value of the reversal rate, averaged for all three images, was equal to 13.1±2.5 times per minute.

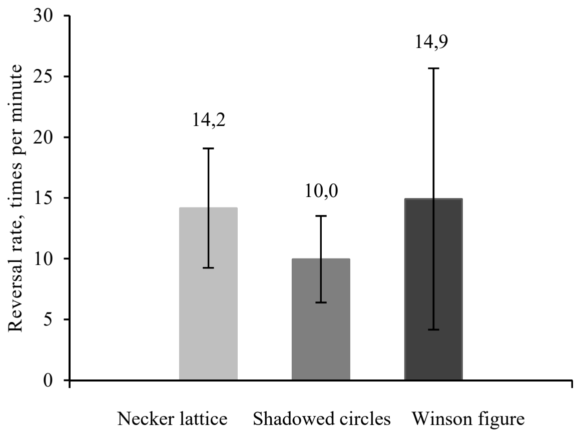

Fig. 6 Reversal rates for all three stimuli. Error bars represent standard deviation (SD) values. Reversal rate values don't differ significantly ($p>0.05$)

Our results quite agree with the data by [7]. The reversal rate for the Necker lattice the authors obtained was 12.5 times per minute. In another study where a single Necker cube was used as a stimulus an average rate of its reversals was about 13 times per minute [14]. Unfortunately, we could not find any information about the studies where the other two ambiguous images (shadowed circles and the Winson figure) were used to test multistable perception. Further research is needed to check why the shadowed circles image is slightly harder to reverse and whether it is related to some personality traits like, it is in case with the Necker cube. Thus, reproducibility of the reversal rate value suggests that perceptual reversals of the Necker cube (and may be other ambiguous images) do not depend significantly on experimental conditions or image properties. This fact indicates that bottom-up processes are not crucial for bistable perception.

We demonstrated similar reversal rates for ambiguous images of different types, which perceptual reversals result from different image features. This finding supports the top-down approach to explaining bistable perception mechanism.

C. Stability Durations

The analysis of the periods of stable perception (stability durations or dwell times) indicated that all participants had a bias towards one or another interpretation of each ambiguous image – a preferred percept, which observation time was longer in comparison to the alternative one. For the two images – the Necker lattice and shadowed circles, - there was a "commonly preferred percept", which stability periods were significantly longer ($p<0.05$) in comparison to the alternative (non-preferred) percept for all (or almost all) participants (Fig. 7).

The Necker lattice had a preferred percept of cubes seen from above. 17 out of 18 observers saw it in this perspective for longer periods. Some researchers mention that Necker cube is preferably seen in the perspective from above, e.g. [7], [14]. This "viewing-from-above" bias [14] is obviously due to our usual viewpoint, when most objects are placed below our line of sight, so visual system is more adapted to this perspective.

As for the shadowed circles most observers (12 out of 14, the other four participants couldn't see the reversals of this image) saw them as spheres but not as cavities or holes for longer time. This bias towards convex shape is obviously the result of its prevalence in the natural environment. Our visual system demonstrates a tendency to reject the possibility of hollow shapes and to interpret the images as being convex; a famous "Hollow-Face illusion" (or "Hollow-Mask illusion", when one sees a concave mask of a face as a normal convex face but lit from below) provides a good example of this bias [15]. This asymmetry in response to symmetrical stimuli (the Necker lattice and shadowed circles) implies that some high-level process (may be some kind of decision making) is involved in bistable perception, at least of the stimuli of this kind, that is perspective reversing figures.

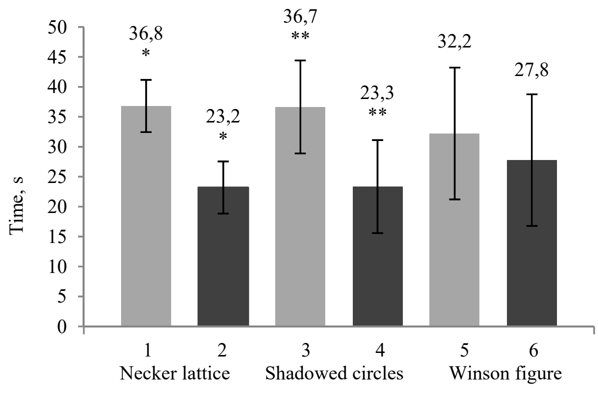

Fig. 7 Stability durations (total sum over one minute) of alternative percepts of the three images 1 – cubes seen from above, 2 – cubes seen from below; 3 – spheres, 4 – holes; 5 – Indian, 6 – Eskimo. Error bars represent SD values. *,** - statistically significant difference ($p<0.05$)

When watching the Winson figure eight observers had a bias toward the Indian percept, the other eight – towards the

Eskimo (the other two had difficulty with reporting reversals of this image as we have mentioned above). So there was a preferred percept for each observer but we cannot say of a "commonly preferred percept", which would be preferred by the majority of the observers.

In Fig. 7 one can see that the average stability durations for the preferred percepts for the Necker lattice and shadowed circles (1 and 3) are almost the same (so are the non-preferred stability durations, 2 and 4). So if we count a ratio of preferred to non-preferred percept observation time for these two images, for both we get the same number of 1.6.

The Necker lattice and shadowed circles belong to the same category of the ambiguous images, which are characterized by alterations in a perceived depth. Their three-dimensional interpretations are based on monocular depth cues such as perspective (in case of the Necker lattice) and shading (shadowed circles). Obviously for the images of this kind the stability duration is more constant temporal characteristic that doesn't depend on the stimulus features, in comparison to the reversal rate, which was slightly lower for shadowed circles (Fig. 6). One could suppose that bistable perception of these images may be influenced by the viewing condition, namely binocular/monocular viewing. Our previous research proved it not to be the case [16]. The mean number of reversals during both monocular and binocular viewing of the two images stayed nearly the same (did not differ significantly), which is another strong evidence in favor of the top-down approach.

Since for the Winson figure each observer had a bias towards one or another percept – Indian or Eskimo, - we found a ratio between individually preferred and non-preferred percept observation time; it appeared to be 1.8, which is close to the result obtained for the other two images. Therefore, though the three studied images belong to different types in terms of ambiguity sources; their bistable perception is characterized by almost the same ratio of preferred to non-preferred percept observation time. This fact provides another evidence for the top-down hypothesis explaining perceptual reversals.

IV. Conclusion

We have found the mean value of a reversal rate for the three ambiguous images that belong to different types. The first type includes the Necker lattice and shadowed circles perceived both as spheres or cavities. They are the images with monocular depth cues - perspective for the Necker lattice and shading for the circles. Their reversals arise from ambiguous three-dimensional interpretation of two dimensional drawings (perspective reversing figures).

The image of the second type is the Winson figure (the Indian/Eskimo picture), which belongs to the content reversal category as its content may have different interpretations.

The statistical analysis of the data with Mann-Whitney U-test, Wilcoxon single-rank test and Friedman test has shown that the perceptual reversal rate for all three ambiguous images has similar values and does not depend much on the image features. We have also calculated the periods of stable perception (stability durations) of each percept for all three images. It has turned out that the images with monocular depth cues have a "commonly preferred percept", that is a percept observed by the most people for a longer period. This bias can be explained in terms of the most natural viewing conditions: for both images the preferred percept is the one that is more usual for the natural environment – cubes seen from above and convex hemispheres.

We have found a ratio of preferred to non-preferred percept observation time for the three images. For the Necker lattice and the shadowed circles, that is the perspective reversing figures; this ratio was the same – 1.6. It means that total stability duration is more constant temporal characteristic for the images of this kind than the reversal rate is. For the Winson figure this ratio was 1.8. Thus, our findings on the similar temporal characteristics of bistable perception of images, which ambiguity is caused by different factors, enable us to suggest the existence of a common mechanism of multistable perception that operates on higher levels of visual system and which top-down influences provide perceptual reversals during multistable perception.

References

[1] J. Kornmeier, and M. Bach, "Ambiguous figures – what happens in the brain when perception changes but not the stimulus," *Front. Hum. Neurosci*., 2012, vol. 6, pp, 1-23.
[2] T.C. Toppino, and G.M. Long, "Selective adaptation with reversible figures: don't change that channel", Percept Psychophys., 1987, vol. 42, pp. 37–48.
[3] G.M. Long, and A.D. Olszweski, "To reverse or not to reverse: when is an ambiguous figure not ambiguous?", Am J Psychol., 1999, vol. 112, pp. 41–71.
[4] J. Kornmeier, and M. Bach, "Early neural activity in Necker-cube reversal: evidence for low-level processing of a gestalt phenomenon", *Psychophysiology*, 2004, vol. 41, iss. 1, pp. 1-8.
[5] I. Rock, S. Hall, and J. Davis, "Why do ambiguous figures reverse," Acta Psychologica, 1994, vol. 87, iss. 1, pp. 33–59.
[6] D.A. Leiopold, and N.K. Logothetis, "Multistable phenomena: changing views in perception," *Trends Cogn. Sci*., 1999, vol. 3, iss. 7, 1 July, pp. 254–264.
[7] J. Kornmeier, Ch.M. Hein, and M.Bach, "Multistable perception: When bottom-up and top-down coincide," *Brain and Cognition*, 2009, vol. 69, pp. 138-147.
[8] R. van Ee, L.C.J. van Dam, G.J. Brouwer, "Voluntary control and the dynamics of perceptual bi-stability", *Vis Res*, 2005, vol 45, pp. 41-55.
[9] J. Kornmeier, S.P. Heinrich, H. Atmanspacher, and M. Bach, "The reversing "Necker Wall" - a new paradigm with reversal entrainment reveals an early EEG correlate," *Investigative Ophthalmology and Visual Science*, 2001, vol. 42, p. 409.
[10] J.E. Bergum, B.O. Bergum, "Self-perceived creativity and ambiguous figure reversal-rates", *Bull Psychonom Soc*, 1979, vol. 14, no 5, pp. 373-374.
[11] B.O. Bergum, J.E. Bergum, "Creativity, perceptual stability, and self-perception", *Bull Psychonom Soc,* 1979, vol. 14, no 1, pp. 61–65.
[12] H. Klintman, "Original thinking and ambiguous figure reversal rates", *Bull Psychonom Soc,* 1984, vol. 22, no 2, pp. 129–131.
[13] J. Wernery, "Bistable perception of the Necker cube in the context of cognition and personality", ETH, 2013.
[14] N.F. Troje, and M. McAdam, "The viewing-from-above bias and the silhoutte illusion", *i-Perception,* 2010, vol. 1, iss. 3, pp. 143–148.
[15] V.S. Ramachandran, "Perceiving Shape from Shading", *Sci. Amer.*, 1988, vol. 259. no 2, pp. 76-83.
[16] V.A. Maksimova, D.N. Podvigina, "Ambiguous figures perception under binocular and monocular viewing conditions", *Perception,* 2014, vol 43, ECVP Abstract Supplement, p. 111.