International Cartographic Association
Association Cartographique Internationale

What moderates the terrain reversal effect in shaded relief maps?

Arzu Çöltekin [a,*], Amy L. Griffin [b], Rahel Ganarin [a], Victoria Rautenbach [c], Serena Coetzee [c], Azile Mdleleni [c]

[a] *FHNW University of Applied Sciences Northwestern Switzerland, arzu.coltekin@fhnw.ch, rahel.ganarin@fhnw.ch*
[b] *RMIT University, amy.griffin@rmit.edu.au*
[c] *University of Pretoria, victoria.rautenbach@gmail.com, serena.coetzee@up.ac.za, azile.mdleleni@tuks.co.za*

* Corresponding author

Keywords: shaded relief, terrain reversal effect, relief inversion effect, visual illusion

Abstract:

Shaded relief terrain representations are often used by map makers to produce a depiction of terrain that the map reader can understand intuitively. Such representations use modelled shadows cast by a light source that is positioned at a particular orientation with respect to the terrain, typically an azimuth in the northwestern quadrant. While this method often produces a depiction of the terrain that helps map readers develop an accurate understanding of the terrain features, it is affected by a perceptual illusion. This illusion can make terrain features appear to sink into the landscape rather than protrude from it and vice versa. It occurs when the modelled light source that produces shadows is oriented at angles other than those from which the human visual system assumes they will come. Previous research on this inversion phenomenon has documented its occurrence in shaded relief maps (Imhof, 1967; Bernabé-Poveda and Çöltekin, 2015; Biland and Çöltekin, 2017) as well as satellite imagery (Saraf et al., 1996; Bernabé-Poveda et al., 2005; Çöltekin and Biland, 2019).

One theory of human vision proposes that our visual system assumes that light comes from above when it is trying to infer shape from shadows (Sun and Perona 1998; Ramachandran 1988). This assumption is called the overhead illumination bias, or the "light-from-above" prior. Researchers have shown that the angle that the visual system assumes that light comes from is not directly overhead, but from a leftward overhead angle (Sun and Perona, 1998). They inferred this from the slightly better performance in judging shapes when light comes from leftward angles than from right-ward angles. This is called the left bias, and Sun and Perona suggest that it arises because right-handed people place lights to the left when they want to illuminate a surface, to avoid obscuring shadow being cast on the surface. They suggest their failure to observe a right bias in left-handed people to left-handed people adjusting their behaviour to survive in a world designed for right-handers, who make up the majority of the world's population (90%). Studies of shaded relief and the occurrence of the terrain inversion illusion have also documented a left bias, wherein people do better at judging shape when the light comes from the left rather than the right (Çöltekin and Biland, 2019; Çöltekin et al., 2018).

Other work has shown that experience can change the "light-from-above" prior's influence on how people perceive shape from visual stimuli (Adams et al., 2004). Few studies of the terrain inversion illusion have tried to control for the different sun angles people experience across their life courses when they live at different latitudes. Because of the Earth's tilt, in the northern hemisphere, the sun swings through southerly aspects as it moves through the sky across a day and the seasons, while it swings through northerly aspects as it moves through the sky in the southern hemisphere. Thus, we wondered whether southern hemisphere map readers would perceive landforms differently when viewing shaded relief. In other words, we wondered whether the illusion has its basis in the light we perceive when we are out and about in the environment, or in how we position light at night and when we are inside.

To investigate this, we undertook a controlled experiment with 234 participants who had lived the majority of their lives in either the northern or southern hemisphere and made sure to balance the sample by handedness so that we had similar numbers of left- and right-handed participants from each hemisphere. Handedness was further confirmed using the Edinburgh Handedness Inventory Short Form (Veale, 2014). The sample was also balanced by gender. Participants were recruited through the scientific study panel provided by Prolific (http://prolific.co).

The experimental task required participants to view a set of 154 shaded relief terrain images constructed by systematically varying the azimuth of the light source (Figure 1) and report whether the landform marked with A-B-C was a ridge or a valley using a 6-point Likert scale that ranged from 1 ("clearly a valley") to 6 ("clearly a ridge"). This

Abstracts of the International Cartographic Association, 6, 40, 2023.
31st International Cartographic Conference (ICC 2023), 13–18 August 2023, Cape Town, South Africa.
https://doi.org/10.5194/ica-abs-6-40-2023 |

Likert scale value was then decomposed into two data points: accuracy (a binary value of correct/incorrect), and confidence (an ordinal value ranging from 0-2). Values of 3 or 4 were given a confidence value of 0, values of 2 or 5 received a confidence value of 1, and values of 1 or 6 received a confidence value of 2.

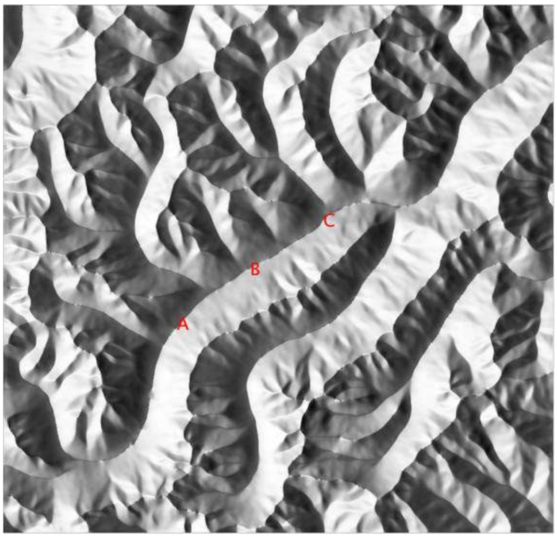

Figure 1. Example experimental stimulus.

The preliminary results of our analysis suggest that there may be performance differences by hemisphere, with northern hemisphere participants identifying the landforms accurately more frequently than southern hemisphere participants.

Acknowledgements

This work was partially funded by a Google Faculty Research Grant to Arzu Çöltekin.

References

Adams, W. J., Graf, E. W., and M.O. Ernst. 2004. Experience can change the 'light-from-above' prior. *Nature Neuroscience*, *7*(10): 1057–1058.

Bernabé-Poveda, M.-A., Callejo, M. A. M., and D. Ballari. 2005. Correction of relief inversion in images served by a web map server. In: *Proc. Of the International Cartographic Conference, ICC 2005*, 9-16 July 2005, A Coruña, Spain. 1–13.

Bernabé-Poveda, M.-A., and A. Çöltekin. 2015. Prevalence of the terrain reversal effect in satellite imagery. *International Journal of Digital Earth*, 8 (8): 640–655.

Biland, J., and A. Çöltekin. 2017. An empirical assessment of the light direction on the relief inversion effect in shaded relief maps: NNW is better than NW. *Cartography and Geographic Information Science*, 44 (4): 358–372.

Çöltekin, A., and J. Biland. 2019. Comparing the terrain reversal effect in satellite images and in shaded relief maps: an examination of the effects of color and texture on 3D shape perception from shading. *International Journal of Digital Earth*, 12(4), 442–459.

Çöltekin, A., Rautenbach, V., Coetzee, S., and T. Mokwena. 2018. Landform perception accuracy in shaded relief maps: a replication study confirms that nnw lighting is better than nw against the relief inversion effect. *International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *42*, 101–106.

Imhof, E. 1967. Shading and shadows. In *Cartographic Relief Representation*, edited by H. J. Steward, Vol. 2007, 159–212. Berlin: Walter de Gruyter GmbH & Co KG.

Ramachandran, V. S. 1988. Perception of shape from shading. *Nature*, 331(6152), 163–166.

Saraf, A. K., J. D. Das, B. Agarwal, and R. M. Sundaram. 1996. False topography perception phenomena and its correction. *International Journal of Remote Sensing*, 17 (18): 3725–3733.

Sun, J., and P. Perona. 1998. Where is the sun? *Nature Neuroscience,* 1 (3): 183–184.

Veale, J. F. 2014. Edinburgh handedness inventory–short form: a revised version based on confirmatory factor analysis. *Laterality: Asymmetries of Body, Brain and Cognition*, 19(2), 164-177

https://doi.org/10.5194/ica-abs-6-40-2023 |