**Supplemental Information: Perceived Three-Dimensional Shape Toggles Perceived Glow**

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## Supplemental Experimental Procedures

### Experiment 1: Shape from Binocular Disparity

**Observers.** We recruited six observers (mean age 23.5 years, SD = 2.59; five female) from the York University Centre for Vision Research in Toronto, Canada. All observers were experienced with other psychophysical experiments, but inexperienced with respect to our experiment. All had normal or corrected-to-normal monocular visual acuity in both eyes, and all had normal stereoscopic acuity, verified using the Randot™ stereoacuity test.

**Stimuli.** There were two types of stimuli. Dark-valley stimuli were 3D surfaces whose peaks had high luminance and valleys had low luminance. Each bright-valley stimulus was obtained by inverting the depth of a dark-valley stimulus, such that peaks became valleys and vice versa, but the luminance of each point on the surface was unchanged. Below we describe the details of how we did this, and we also provide Matlab code that generates the stimuli.

***Step 1.*** We generated a depth map Z[i,j], a sample of low-pass Gaussian noise on a 512 x 512 grid, that would determine the 3D shape of the surface. The noise had a sharp upper cut-off frequency of 9 cycles per square width, and an element-wise mean of 0 and standard deviation of 1.

***Step 2.*** We generated a luminance map L[i,j], by rendering the depth map Z[i,j] as a 3D surface under diffuse light using Radiance, a 3D rendering software package [S1]. We used the depth map Z[i,j] to generate a triangular mesh in virtual 3D space. The virtual triangular mesh was 10 x 10 cm, and its surface depth had a standard deviation of 0.68 cm. This surface had a reflectance of 30%. To strengthen the binocular disparity cues in our surfaces, we applied a texture of darker, randomly placed splotches (reflectance 18%) to the surface. The simulated light source was a uniform, infinitely distant surface of luminance 832 cd/m$^2$. The light source was almost a complete sphere, and covered the whole sky except for a small circular region (diameter 40º) behind the object, along the observer's line of sight. We excluded the light source from this small region so that it would not be visible in the stimulus as a bright surface behind the object. This lightless region had no effect on the illumination of the visible side of the object, so the object was effectively illuminated uniformly from all directions. We did not render interreflections. We re-scaled the luminances when displaying the stimuli on the monitor, so the absolute luminance values we used for rendering the stimuli in Radiance are not informative. For the actual range of luminances in the stimulus display, see Procedure, below.

We rendered this scene using orthographic projection, to produce a 512 x 512 pixel image of the surface viewed face-on. This is the luminance map L[i,j]. Because the light was diffuse, the luminance map had high values at the peaks of Z[i,j], and low values in the valleys [S2].

***Step 3.*** We created a pair of dark-valley and bright-valley stimuli by applying the luminance map L[i,j] either to the depth map Z[i,j] or to the reversed depth map -Z[i,j]. We used the Psychophysics Toolbox's [S3] interface to OpenGL to create these stimuli. To show the dark-valley stimulus, we used the depth map Z[i,j] to create a triangular mesh in virtual 3D space, just as in step 2. We applied the luminance map L[i,j] to this surface, so that the luminance of each point on the surface was determined by L[i,j]. In this step, we did not have OpenGL do any shading calculations, so the luminance of each surface point was simply given by L[i,j]. As a result, this stimulus showed the surface Z[i,j] as it would appear when viewed under diffuse light. We generated the bright-valley stimulus in the same way, except that we used the negated depth map -Z[i,j]. Thus the dark-valley and bright-valley stimuli had identical luminance maps, but opposite depth maps.

We rendered these surfaces in OpenGL using perspective projection, with a simulated surface size of 10 x 10 cm and a simulated viewing distance of 74 cm. We rendered a stereoscopic pair of each surface, with a simulated interocular distance of 6 cm. We showed the stereo stimuli on a mirror stereoscope with two Dell Ultrasharp U2412M monitors at a viewing distance of 74 cm. The monitors had a resolution of 1920 x 1200 pixels, a pixel size of 0.2692 mm, and a refresh rate of 60 Hz. We configured the monitors' colour look-up tables to make pixel luminance proportional to frame buffer RGB values. The maximum luminance of the stimuli was 163.6 cd/$m^2$ and the minimum was 1.0 cd/$m^2$.

**Procedure.** All procedures were approved by York University's Human Research Participants Committee (HRPC). All observers provided informed consent prior to running in the experiment.

***Experiment 1A: Glow Condition.*** Each observer ran in one 15-minute block of 200 trials without a break. Each trial showed a dark-valley stimulus and a bright-valley stimulus side by side against a black background. In half of the trials, the dark-valley stimulus was on the left, and in the other half, on the right. Each of the 200 stimulus pairs was based on a different depth map. The stimuli were positioned 7.4 cm to the left and right of the centre of the virtual screen. The observer chose the stimulus that most appeared to glow, where we explained "glow" as a surface that "is emitting light," "has a light source either inside or behind the surface," and "is not just bright because of an external light source." The stimuli stayed on the computer screen until the observer responded with a key press, and the observer had as much time as needed to respond. On response, the screen turned black for 200 ms, then the next trial began. There was no feedback.

***Experiment 1B: Depth Condition.*** Each observer ran in a single 5-minute block of 40 trials. Each of the 40 stimulus pairs was based on a different depth map. This set was different from the set of 200 used in Experiment 1A. In each trial, either a dark-valley stimulus or a bright-valley stimulus was presented at the centre of the screen; half of the trials showed dark-valley, and the other half showed bright-valley, and the two trial types were randomly interleaved. Each stimulus was marked with a probe, which was a blue, blurry disc of 2 mm diameter. The observer indicated whether the probe appeared to be on a peak or a valley of the surface. The stimulus stayed on the computer screen until the observer responded with a key press, and the observer had as much time as needed to respond. On response, the screen turned black for 500 ms, then the next trial began. There was no feedback.

## Experiment 2: Shape from Motion

All methods were the same as in the glow condition of Experiment 1, except that we created an impression of 3D depth by making the stimuli rock back-and-forth in a sinusoidal motion, with an amplitude of 45° and a period of 1.3 seconds. We used the same set of 200 depth maps as in Experiment 1A. A minor difference from Experiment 1 was that we scaled the luminance of the stimuli to a single maximum luminance across all trials, rather than per trial. The luminance scaling used here made no noticeable difference compared to the per-trial luminance scaling in the stereoscopic experiment. The maximum luminance of the stimuli was 62.4 cd/$m^2$ and the minimum was less than 0.1 cd/$m^2$. For a sample pair of stimuli, see Supplemental Movie S1.

## Supplemental References

S1. Ward, G. J. (1994). The RADIANCE lighting simulation and rendering system. Comp. Graph. 459-472.

S2. Langer, M. S. and Zucker, S. W. (1994). Shape-from-shading on a cloudy day. J. Opt. Soc. Am. A *11*, 467-468.

S3. Kleiner, M., Brainard, D. H. and Pelli, D. G. (2007). What's new in Psychtoolbox-3? Perception *36*, 14.

## Author Contributions

Conceptualization, M.K. and R.F.M.; Methodology, M.K., L.M.W., and R.F.M.; Software, M.K., L.M.W., and R.F.M.; Validation: M.K., L.M.W., and R.F.M.; Formal Analysis, M.K.; Investigation, M.K.; Writing – Original Draft, M.K., L.M.W., and R.F.M.; Writing – Review & Editing, M.K., L.M.W., and R.F.M.; Visualization, M.K.; Supervision, L.M.W., and R.F.M.; Project Administration, M.K., L.M.W., and R.F.M.; Funding Acquisition, M.K., L.M.W., and R.F.M.