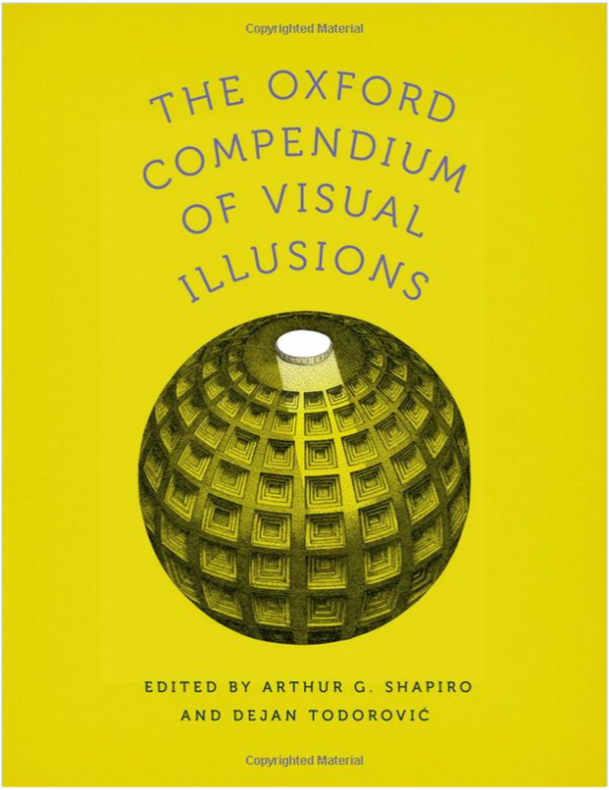
Chapter 78. The Motion Standstill Illusion

George Sperling, Son-Hee Lyu, Chia-huei Tseng, and Zhong-Lin Lu

in



Sperling, G., Lyu, S-H., Tseng, C-H., & Lu, Z-L. (2018). The Motion Standstill Illusion. In Shapiro, A. & Tedorovic, D. (Eds). The Oxford Compendium of Visual Illusions. New York, NY: Oxford University Press. Chapter 78, Pp. 576-579.

Chapter 78
The Motion Standstill Illusion

George Sperling, Son-Hee Lyu, Chia-Huei Tseng, and Zhong-Lin Lu

INTRODUCTION

In the motion standstill illusion, a pattern that is moving quite rapidly is perceived as being absolutely motionless, and yet its details are not blurred but clearly visible. This is a very unusual phenomenon, and it takes very special stimuli to demonstrate it. To understand why motion standstill occurs, it is useful to recognize that even when we keep as motionless as possible, small, involuntary movements of the body and eyes cause the retinal image to make random movements across the retina that are large in relation to details that can easily be resolved (Rossi & Roorda, 2010). During active vision in normal situations, as in walking, the image on the retina continuously undergoes involuntary rapid random excursions that are enormously larger than details of shape, texture, color, and depth that can be easily resolved in the randomly moving retinal image that, despite its uncontrolled random movement, is perceived as being stable (Steinman, Cushman, & Martins, 1982).

Theoretically, motion standstill is a very important phenomenon. It demonstrates that the job of the shape, texture, color, and depth systems is to extract a stable, static percept from the normal, randomly moving visual input. When we do perceive motion, it is the result of a computation by the motion system. When devious experimental manipulations silence the motion system under circumstances that enable the other systems to still operate, we perceive only the stable static image that the shape, texture, color, and depth systems derive from the moving retinal image.

FIVE WAYS TO PRODUCE THE MOTION STANDSTILL ILLUSION

1. Motion standstill can occur with rapidly moving fine-detail images that have been constructed so that the spatiotemporal resolution of the shape-texture-object perception systems exceeds that of the first-order motion system and, incidentally, all other motion systems as well (Sperling, Lyu, & Kim, 2002).
2. Motion standstill occurs with moving color stimuli that are constructed to be equiluminant to silence the first-order motion system, that have insufficient texture to activate the second-order motion system, and that are isosalient to silence the third-order motion system. The requirements of equiluminance and isosalience place severe constraints on the range of possible images but nevertheless leave enough freedom to enable representation of objects that are completely invisible to the motion systems (and therefore cannot produce the sensation of motion) but are perfectly visible to shape, texture, color, and depth systems (Lu, Lesmes, & Sperling, 1999b).
3. Motion standstill occurs when the stereodepth resolution of the depth perception system exceeds that of the third-order motion system (Tseng, Gobell, Lu, & Sperling, 2006).
4. Motion of stimuli that stimulate primarily blue cones selectively disadvantage the motion systems (Cavanagh, Tyler, & Favreau, 1984).
5. Various motion adaptation procedures (prolonged viewing of high-contrast moving stimuli) adapt/fatigue the motion systems sufficiently that a subsequently viewed moving grating appears to be motionless while its shape can still be recovered (Cohen, 1965; Hunzelmann & Spillmann, 1984; MacKay, 1982).

Motion Standstill in High Spatial Frequency Gratings

Motion standstill has been extensively studied experimentally with foveally viewed sine-wave gratings and peripherally viewed annular gratings like those illustrated in Figure IV.78-1 (Lyu, 2010). Foveal grating moving with any temporal frequency between 5 to 10 Hz and a spatial frequency of 16 or 22 c/d (it varied between subjects) produced objective and subjective motion standstill nearly all the time for the three subjects formally tested and also for many others. Subjective standstill means that the grating is visible and appears to be standing still. Objective standstill means (a) that the subject can judge the slant of the grating virtually perfectly but (b) cannot report the direction of motion better than chance and (c) that responses to any aspects of the moving stimulus that is perceived as standing still are statistically indistinguishable from responses to interleaved stimuli that are indeed physically motionless. That is, an observer does not distinguish a stimulus that is moving but is perceived as being motionless from a physically motionless stimulus.

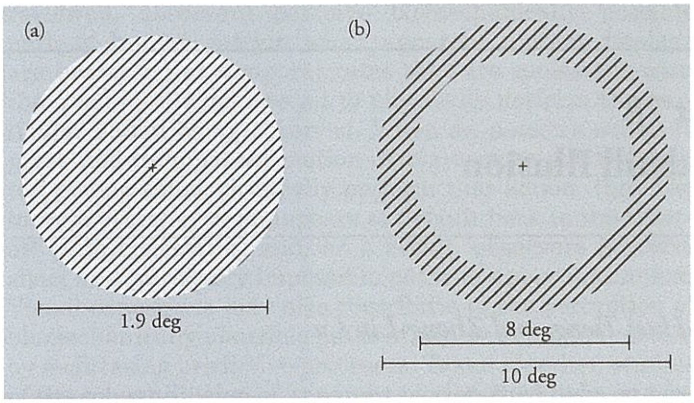


Figure IV.78-1. Snapshots (single frames) of moving sinewave gratings for demonstrating motion standstill in (a) foveal and (b) peripheral viewing. (After Lyu, 2010, with permission.)

The simplest way to experience high spatial frequency standstill is to produce a display (like in Fig. IV.78-1) that has a temporal frequency of about 5 Hz and to view it from various distances. It is usually possible, by moving away from the display, to find a viewing distance at which the slant of the grating is clearly visible but it no longer appears to move. The principle is illustrated in Figure IV.78-2.

Motion Standstill in Equiluminant, Isosalient Chromatic Motion Stimuli

The perception of visual motion is computed by at least three different systems (Lu & Sperling, 1995). The first-order motion system computes motion based on luminance variations. It is exquisitely sensitive and can detect motion with luminance variations of 1 part in 500. Nevertheless, first-order motion cannot be perceived in stimuli that vary in color but are balanced to be precisely equiluminant for the first-order motion system (Lu, Lesmes, & Sperling, 1999a). The stimuli under consideration here (Fig. IV.78-3) were perfectly balanced to reduce first-order contamination to far below threshold (Anstis & Cavanagh, 1983; Lu & Sperling, 2001). Because of the extreme sensitivity of the first-order motion system, the first-order calibration is specific to an observer, to a particular stimulus display, and to the region of the retina in which the stimulus is observed.

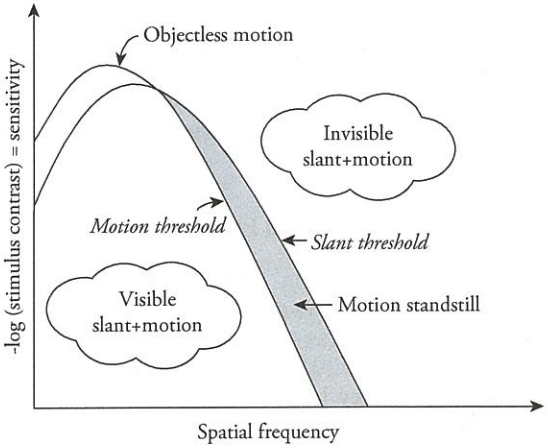


Figure IV.78-2. Schematic illustration of the spatial frequency and contrast that could produce motion standstill for a sinewave grating of a particular temporal frequency, size, and position on the retina. The abscissa represents increasing spatial frequency; the ordinate represents decreasing contrast modulation of the sinewave grating. The line "motion threshold" separates the stimuli for which motion-direction discrimination is possible from those stimuli for which it fails. The line "slant threshold" separates the stimuli for which slant-orientation discrimination is possible from those stimuli for which it fails. Motion standstill occurs in marginal areas where the shape system succeeds and the motion system fails. Objectless motion (not studied here) occurs for stimuli in which contrast is too low to permit shape resolution but nevertheless is sufficient for motion-direction perception. (Figure by George Sperling and Son-Hee Lyu.)

The second-order motion does not respond to luminance directly but to the *variance* of luminance in texture stimuli. It is not relevant to these stimuli because they have insufficient texture.

The third-order motion system responds to salience. Salience in these stimuli is controlled by the relative difference from the background of the red and green regions and by the relative amount of attention they receive from the observer. To achieve the greatest possible contrast, the red output of the display device is set to its maximum value and the green output, which has a greater range, is varied. The green stripes of the grating are then adjusted to isosalience by varying the green saturation, always maintaining equiluminance. When isosalience is achieved, there is no salience variation within the moving grating; therefore there is no salience variation when the grating moves; therefore the third-order motion system has no signal; and therefore no motion is perceived. However, the shape and color systems can function perfectly over a wide range of speeds of the grating, and, over this range, the stimulus will appear motionless to the observer. And of course the observer is absolutely unable to report the direction of motion of the apparently stationary stimulus—it seems to be a stupid question. Motion standstill has been vividly demonstrated for red–green gratings of different spatial and temporal frequencies and for all observers (Lu et al.,1999b).

The first- and third-order calibrations are highly specific to an observer. A change of 0.5% in luminance or 5%

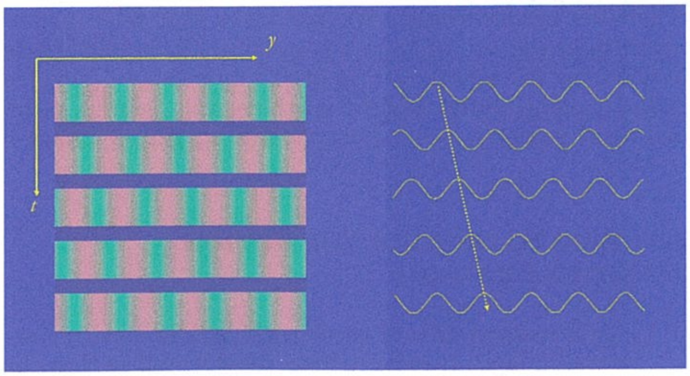


Figure IV.78-3. Five frames of a chromatic sinewave grating in which consecutive frames are translated 90° to the right. When the red and green stripes are calibrated to be equiluminant for a particular observer and then also made to be isosalient (varying the saturation of green so that it appears as different from the background as red) then this five-frame display will appear to be standing still even though nearly everyone else who is looking at it (but not personally calibrated) will see it as obviously moving to the right. (Figure by Zhong-Lin Lu and George Sperling.)

in saturation changes a display from standstill to obvious motion. Therefore, even while the calibrated observer is consistently reporting standstill to a particular display, everyone else (being uncalibrated) looking at the same display is likely to see it as obviously moving, as indeed it is!

Because human color vision is trichromatic, and because only two dimensions of color have been used to produce equiluminance and isosalience (which are each one-dimensional), there is one extra dimension available to produce an enormous range of differently colored equiluminant and isosalient stimuli. Because of technical difficulties, this potential range has hardly been explored.

Stereomotion Standstill

When a dynamic random-dot stereogram as in Figure IV.78-4 produces a horizontal depth grating that translates upward or downward, there are no monocular cues to motion or form and no first-order or second-motion system activation. However, the near plane of the grating tends to be seen as figure (high salience) versus the background (low salience). The moving salience grating is a fine third-order motion stimulus at temporal frequencies of 3 Hz and lower. At 4 to 5 Hz, motion direction discrimination falls to chance, but pattern discrimination (which is one of three possible spatial frequencies) is very accurate, and the perceived speed is mostly judged as zero (i.e., motion standstill; Tseng et al., 2006). Motion standstill in this third-order motion stimulus follows the regime outlined in Fig. IV.78-2 for first-order motion stimuli. Motion standstill in third-order motion system differs from first-order motion standstill mainly in the lower spatial and temporal resolution of the third-order motion system.

Blue-Cone Motion Standstill

Because blue cones make virtually no contribution to luminance, they do not significantly activate the first-order motion system (Herrera et al, 2013). Therefore, blue-cone isolating stimuli offer an opportunity for studying motion standstill in the third-order motion system, where it is much easier to achieve than in the first-order system. However, there has been no systematic study of motion standstill with blue-cone isolating stimuli. Motion slowdown has been studied with stimuli that stimulate mostly but not exclusively blue cones (Cavanagh et al., 1984), and motion standstill has occasionally been observed.

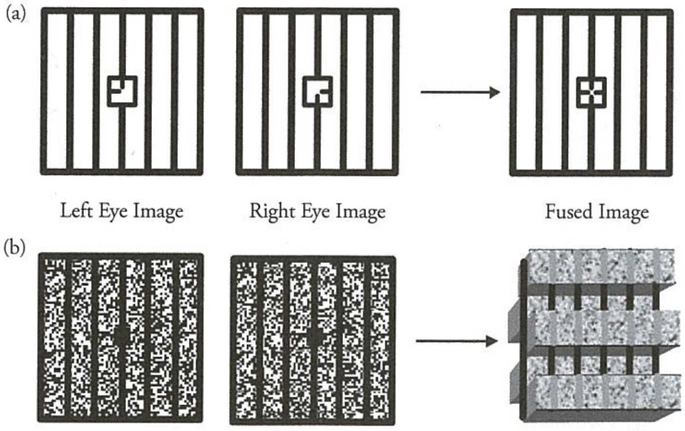


Figure IV.78-4. (a) A stereo stabilizing pattern to insure proper fixation. (b) One frame of a left- and right-eye image of a dynamic random-dot stereogram that produces a raised horizontal grating moving upward or downward. Binocularly free-fusing the left- and right-eye images in (b) produces a stereo perception similar to the representation of the fused image. (After Tseng et al., 2006.)

Standstill Via Motion Adaptation

Cohen (1965) used a variety of stimuli to study peripheral motion adaptation and motion aftereffects. After prolonged viewing between 8.5° to 11° peripherally, linearly translating dots and squares occasionally appeared to stand still. MacKay (1982) reported standstill of a moving extrafoveal grating. Subsequently, Hunzelmann and Spillmann (1984) used slowly rotating black and white disks presented in the periphery to measure the viewing time required for subjects to perceive standstill. The disks appeared to slow down and come to a standstill within 5 to 25 s.

CONCLUSIONS

The motion standstill illusion can be observed in a wide variety of special moving stimuli that either disadvantage or fatigue the motion systems to the point where no motion is perceived but where the shape, texture, color, and depth systems are still able to function sufficiently to extract a stable image from the moving display.

ACKNOWLEDGMENTS

This work was supported in part by National Science Foundation Award BCS-0843897.

REFERENCES

Anstis, S., & Cavanagh, P. (1983). A minimum motion technique for judging equiluminance. In J. D. Mollon & E. T. Sharpe (Eds.), *Colour vision* (pp. 155–166). New York: Academic Press.

Cavanagh, P., Tyler, C. W., & Favreau, O. E. (1984). Perceived velocity of moving chromatic gratings. *Journal of the Optical Society of America A, 1*(8), 893–899.

Cohen, R. (1965). Adaptation effects and after effects of moving patterns viewed in the periphery of the visual field. *Scandinavian Journal of Psychology, 6*, 257–264.

Herrera, C., Sun, P., Groulx, K., Wright, C., Chubb, C., & Sperling, G. (2013). How do the S-, M- and L-cones contribute to motion luminance assessed using minimum motion? *Journal of Vision, 13*(9), 1021.

Hunzelmann, N., & Spillmann, L. (1984). Movement adaptation in the peripheral retina. *Vision Research, 24*(12), 1765–1769.

Lu, Z.-L., Lesmes, L. A., & Sperling, G. (1999a). Perceptual motion standstill in rapidly moving chromatic displays. *Proceedings of the National Academy of Sciences USA, 96*, 15374–15379.

Lu, Z.-L., Lesmes, L. A., & Sperling, G. (1999b). The mechanism of isoluminant chromatic motion perception. *Proceedings of the National Academy of Sciences USA, 96*(14), 8289–8294.

Lu, Z-L., & Sperling. G. (1995). The functional architecture of human visual motion perception. *Vision Research*, *35*, 2697–2722.

Lu, Z.-L., & Sperling, G. (2001). Sensitive calibration and measurement procedures based on the amplification principle in motion perception. *Vision Research*, *41*, 2355–2374.

Lyu, S.-H. (2010). Studies of human motion processing: Motion standstill in luminance- and contrast-modulated motion and fMRI brain imaging of stereo third-order motion (Doctoral thesis). University of California, Irvine.

MacKay, D. (1982). Anomalous perception of extrafoveal motion. *Perception*, *11*, 359–360.

Rossi, E. A., & Roorda, A. (2010). The relationship between visual resolution and cone spacing in the human fovea. *Nature Neuroscience*, *12*(2), 156–157.

Sperling, G., Lyu, S.-H., & Kim, H. (2002). Apparent standstill of rapidly moving first-order and second-order motion stimuli [Abstract]. *Perception*, *31*(Suppl.), 100.

Steinman R. M., Cushman W. B., & Martins A. J. (1982). The precision of gaze. *Human Neurobiology*, *1*, 97–109.

Tseng, C.-H., Gobell, J. L., Lu, Z.-L., & Sperling, G. (2006). When motion appears stopped: Stereo motion standstill. *Proceedings of the National Academy of Sciences, USA*, *103*, 14953–14958.