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Two competing mechanisms underlying neon color spreading, visual phantoms and grating induction

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Abstract

Neon color spreading is closely related to the photopic visual phantom illusion, since these two completion phenomena are characterized by in-phase lightness induction, and the only difference in the stimulus configuration is the difference in the inducer height. This idea was supported by the present study. Neon color spreading showed almost the same function of critical spatial frequency as photopic visual phantoms (Experiment 1), and the critical spatial frequency was constant as the inducer height was changed (Experiment 2). We also examined the relationship between neon color spreading and grating induction (characterized by counterphase lightness induction) in critical spatial frequency (Experiment 3) and in magnitudes of lightness induction (Experiment 4) as a function of the inducer height. The inducer height at which in-phase (neon color spreading) appearance gave way to counterphase (grating) induction was approximately 0.1 deg. These results suggest that neon color spreading shares a common neural mechanism with the photopic visual phantom illusion and that this mechanism is different from, and competes with, the mechanism of grating induction.

Keywords: Grating induction; Neon color spreading; Phase; Photopic phantoms; Visual phantoms

1. Introduction

Neon color spreading is a striking visual illusion which produces apparent completion of color or lightness (Van Tuijl, 1975; Van Tuijl & de Weert, 1979; Redies & Spillmann, 1981; Redies, Spillmann, & Kunz, 1984; Bressan, Mingolla, Spillmann, & Watanabe, 1997) (Fig. 1). While a large body of research has been devoted to neon color spreading, little is known about its relationship to other completion phenomena such as visual phantoms. The visual phantom illusion was first discovered as 'moving phantoms' (Rosenbach, 1902; Tynan & Sekuler, 1975) because of its strong dependence on motion. It was later revealed that phantoms can be generated by flickering the grating (flickering phantoms) (Genter & Weisstein, 1981) as well as by low-luminance stationary gratings under dark adaptation (stationary phantoms) (Gyoba, 1983). Although phantoms are much more visible at scotopic or mesopic adaptation levels than at photopic levels (scotopic phantoms: Fig. 2b and d), we recently proposed a new phantom illusion which is fully visible in photopic vision (photopic phantoms: Fig. 2f and h) (Kitaoka, Gyoba, & Kawabata, 1999).

Although the relationship between neon color spreading and visual phantoms has been ignored so far, it may be fruitful to investigate the possibility that they share some common mechanisms. First, scotopic phantoms resemble neon color spreading, especially when both effects are induced by sinusoidal-wave luminance changes (Fig. 2a–d), where white or black 'mists' are perceived in both cases. However, lightness-induction mechanisms underlying these two types of completion are different from each other: neon color spreading is characterized by in-phase lightness induction (Van Tuijl, 1975), whereas scotopic phantoms are based upon

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counterphase lightness induction (McCourt, 1994; May, Brown, & Roberts, 1999). In contrast, photopic phantoms are characterized by in-phase lightness induction (Kitaoka et al., 1999) and thus resemble neon color spreading (Fig. 2e–h). The only difference in stimulus configurations is the difference in the height of inducing grating. The height is small for neon color spreading (Fig. 2e and g), whereas it is typically large for photopic phantoms (Fig. 2f and h). Therefore, there is a possibility that both illusions belong to a common class of completion phenomena.

In relation to this issue, the grating induction effect has been investigated as a closely related phenomenon to visual phantoms (McCourt, 1982, 1994). Grating induction is characterized by counterphase lightness induction, which appears when luminance of the gap is placed between the highest and lowest luminances of inducing gratings (Fig. 3a). There is an argument proposed by McCourt (1994) who claimed that the scotopic phantom illusion be a kind of grating induction. This argument is discussed in our separate article (Kitaoka, Gyoba, Kawabata, & Sakurai, in press). Briefly, it is true that both phenomena are based upon counterphase lightness induction, yet scotopic phantoms appear continuous with the inducing grating, while grating induction does not; this reason might be attributed to the difference in types of perceptual transparency.

By the way, what happens if the inducer height is shortened in the figure of grating induction? Very faint but in-phase lightness induction appears (Fig. 3b), though the effect of this kind has not been reported to occur (Van Tuijl & de Weert, 1979; Anderson, 1997). The observed effect can be attributed to neon color spreading since its lightness induction is in-phase.

In this study, we extensively examined these issues and presented two major suggestions. One is that neon color spreading and visual phantoms could be included in the same phenomenon of perceptual completion given by connecting inducers with induced areas. The other is that there might be two competing neural mechanisms underlying these three phenomena (neon color spreading, visual phantoms and grating induction), i.e. in-phase and counterphase lightness induction systems, which might reflect different sources or V1 neurons from which the information of lightness induction is provided.

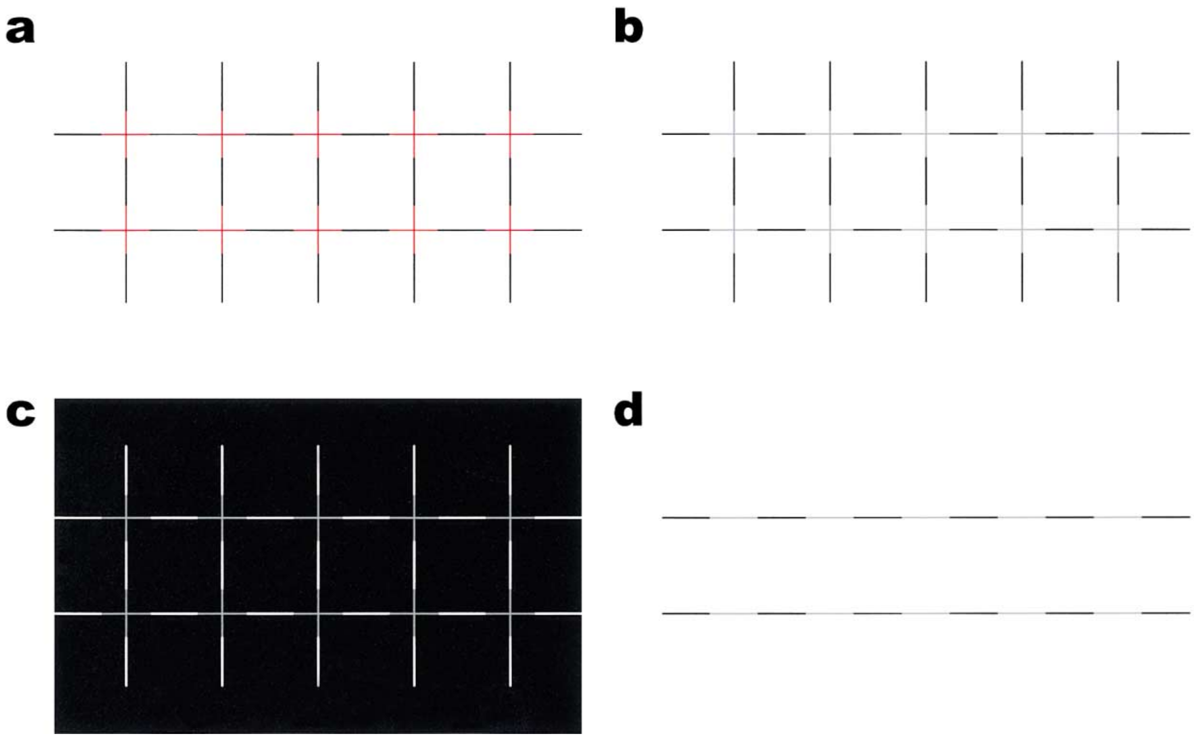

Fig. 1. Examples of neon color spreading. (a) When a red cross is inserted into a larger cross, an illusory patch appears. The patch is like a veil tinted red and appears to hover in front of the red cross. The shape is round or diamond. (b) Example of achromatic neon color spreading, in which lightness is filled in the patch. (c) Although demonstrations (a) and (b) are typical for neon color spreading, a version of the reversed contrast polarity can also produce neon color spreading. (d) A pair of striped lines can also produce neon color spreading. In this figure, observers see vertical illusory contours connecting the joints of line segments and find in the gap lightness induction in phase with the inducing lines. In these and following figures, the luminances of gaps or backgrounds are homogeneous.

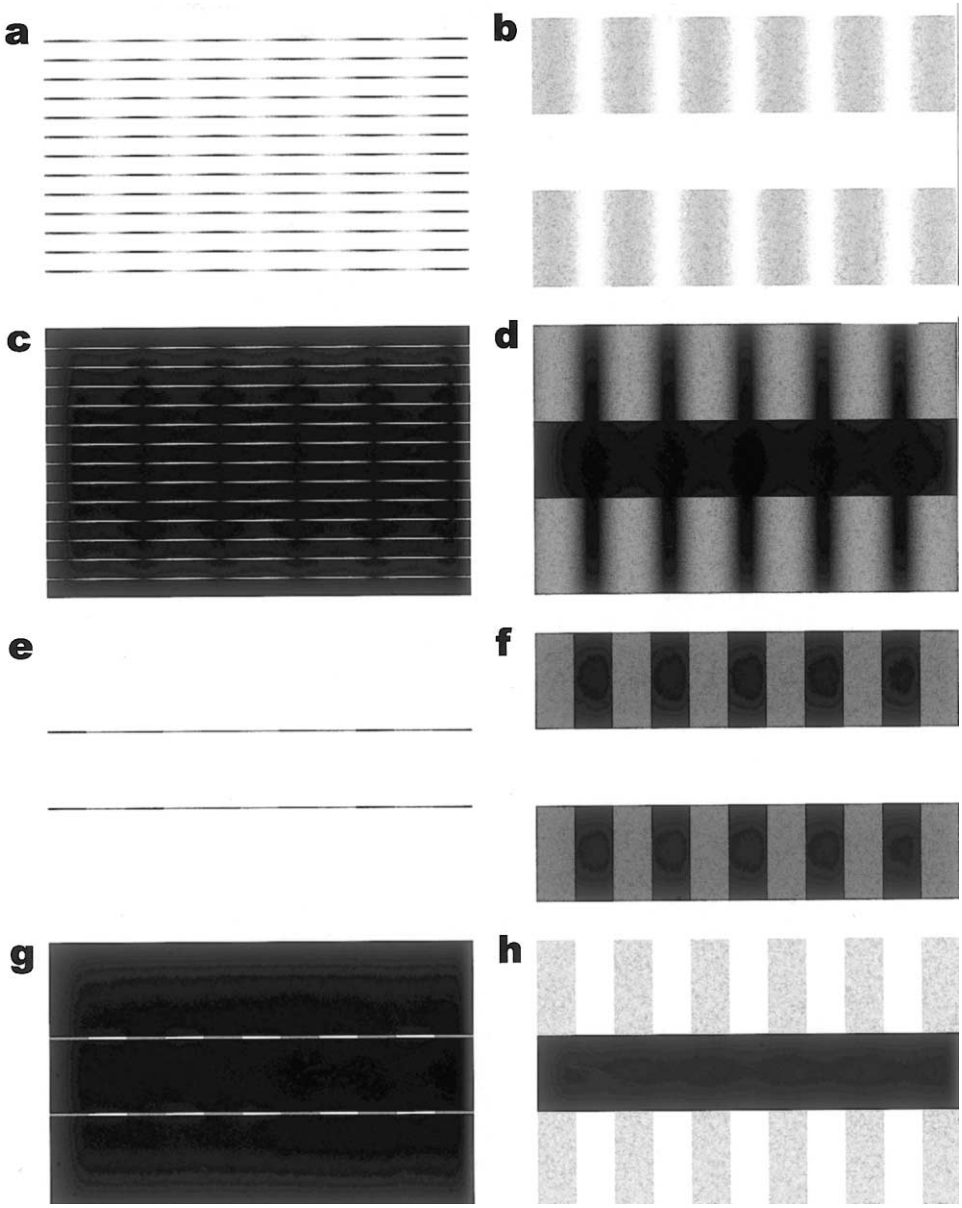

Fig. 2. Resemblance between neon color spreading and visual phantoms. (a) Variation of neon color spreading, in which inducing lines consist of sinusoidal-wave luminance modulation. 'White mists' are perceived across and in front of the background. This appearance resembles 'white phantoms' shown next. (b) When the occluder luminance is the same as the highest luminance of the sinusoidal-wave inducing grating, white phantoms appear connecting the light regions of the grating. (c) Variation of neon color spreading, in which inducing lines consist of sinusoidal-wave luminance modulation. 'Black mists' are perceived across and in front of the background. This appearance resembles 'black phantoms' shown next. (d) When the occluder luminance is the same as the lowest luminance of the sinusoidal-wave inducing grating, black phantoms appear, connecting the dark regions of the grating. (e) Version of neon color spreading, the same as Fig. 1d. This in-phase appearance resembles the white-occluder version of photopic phantoms shown next. (f) Photopic phantoms with a white occluder, in which in-phase phantoms are observed. (g) Version of neon color spreading, in which the contrast polarity of (e) is reversed. We tested this version in Experiments 1 and 2. Observers saw vertical illusory contours connecting the joints of line segments and filled-in lightness induction in phase with the inducing lines. This in-phase appearance resembles the black-occluder version of photopic phantoms shown next. (h) Photopic phantoms with a black occluder, in which in-phase phantoms are observed.

2. Experiment 1

To examine whether neon color spreading shares the characteristic of visual phantoms, we measured critical spatial frequency of neon color spreading (Fig. 2g) as a function of the gap between the upper and lower inducing lines, since this function is one of the unique characteristics of visual phantoms. Critical spatial frequency refers to the threshold spatial frequency of inducing gratings at which completion effects can be visible or not. For visual phantoms, the critical spatial frequency decreases as the gap increases (Gyoba, 1983; Kitaoka et al., 1999).

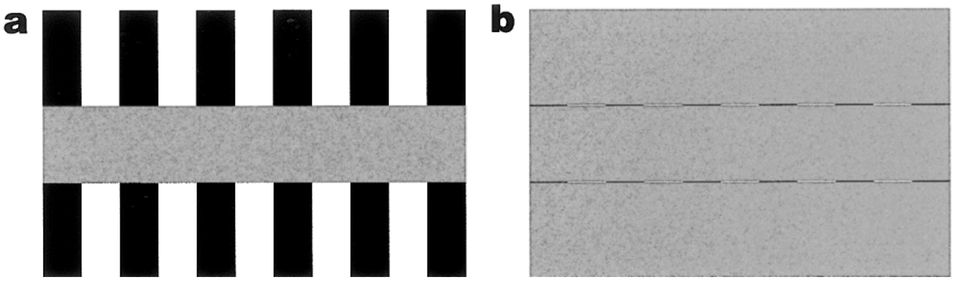

Fig. 3. (a) Example of grating induction, in which counterphase lightness induction is perceived in a homogeneous gray gap. (b) Figure in which inducing lines are black and white while the gap is the intermediate lightness. This figure may render very faint in-phase lightness induction. This version might be able to be attributed to neon color spreading. The only difference between (a) and (b) is the difference in the inducer height. Note: to minimize after-effects, adapt to a uniform white area before viewing either panel. The effect is weaker in reproduction and may not elicit an illusion in some viewers.

2.1. Methods

2.1.1. Subjects

Six naïve subjects participated. All subjects had normal or corrected-to-normal vision.

2.1.2. Apparatus

Stimuli were generated by a Cambridge Research graphics card (VSG 2/3) mounted on a PC (DELL OptiPlex GX1) and displayed upon a monitor (IDEK MF8617) placed in a light room (115 lx on the display table). The monitor was gamma-corrected.

2.1.3. Stimuli

The stimuli were a pair of lines modulated with sinusoidal-wave or square-wave luminance changes, the size of which was 12.0 deg (wide) × 0.0125 deg (high). The distance or the gap between the two inducers was varied from 0.4 to 3.6 deg in steps of 0.4 deg. The highest and lowest luminances of the inducers were 47.65 cd/m^2 and 24.98 cd/m^2 (contrast was 0.31), respectively. The luminance of the background including the gap was 2.30 cd/m^2.

2.1.4. Procedure

Subjects were individually tested. Their heads were fixed with a chin rest and a headrest. They observed stimuli through natural pupils, with the viewing distance being 138 cm. A trial started when they pushed the start key. We used the method of limits. In the ascending case, we started with inducing gratings of low spatial frequency that could fully produce neon color spreading. Each presentation time was 2 s. If subjects saw neon color spreading, the spatial frequency was raised by 8% after a 1 s interval. Their task was to press the response key when they could not see neon color spreading. The spatial frequency when they responded was recorded as critical spatial frequency. In the descending case, we started with inducing gratings of high spatial frequency that could not produce neon color spreading. If subjects did not see neon color spreading, spatial frequency was lowered by 8%. Their task was to press the response key when they saw neon color spreading. The spatial frequency when they responded was recorded as critical spatial frequency. The test order was ADDAADDA or DAADDAAD (A denotes the ascending series, while D denotes the descending series). The order of stimulus conditions (two types of inducer × nine types of gap) was randomized.

2.2. Results and discussion

Fig. 4 shows the result. The critical spatial frequency of neon color spreading decreases as the gap increases ($F_{8,40} = 89.94$, $P < 0.01$). This decreasing function is quite similar to that of the visual phantom illusion. This result strongly supports the idea that neon color spreading shares the same underlying mechanism with visual phantoms.

There was no significant difference in critical spatial frequency between the sinusoidal-wave and square-wave inducers. In previous reports, scotopic phantoms showed a higher critical spatial frequency with the

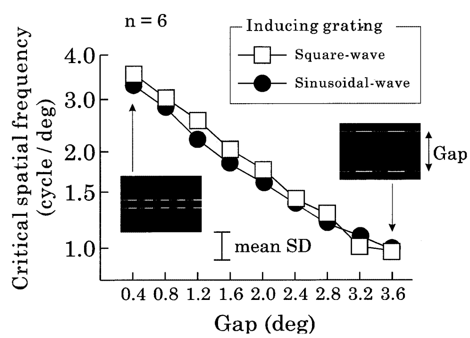

Fig. 4. Critical spatial frequency of neon color spreading as a function of the gap between the upper and lower inducing lines. Critical spatial frequency was a decreasing function of the gap, which is quite similar to the function of visual phantoms. There was no significant difference between sinusoidal-wave and square-wave inducing lines.

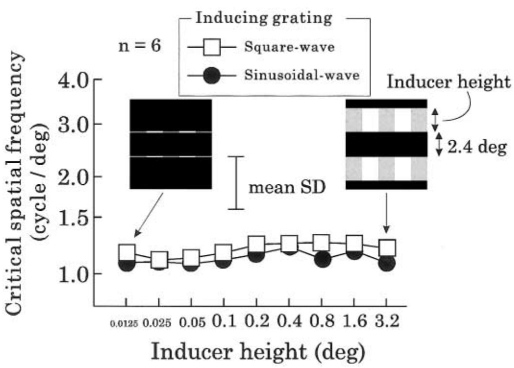

Fig. 5. Critical spatial frequency as a function of the height of inducing gratings. The critical spatial frequency was constant over tested heights. There was no significant difference between sinusoidal-wave and square-wave inducing gratings.

sinusoidal-wave inducer than with the square-wave inducer (Gyoba, 1983), while photopic phantoms gave a small difference (Kitaoka et al., 1999) (precisely speaking, photopic phantoms showed slightly higher spatial frequency with the square-wave inducer than with the sinusoidal-wave one when the gap was large). In this respect, neon color spreading showed a characteristic even closer to that of the photopic phantom illusion than that of the scotopic phantom illusion.

3. Experiment 2

Experiment 1 showed that the spatial frequency characteristic of neon color spreading closely resembles that of the photopic visual phantom illusion. Moreover, both phenomena are characterized by in-phase lightness induction. The only difference in the stimulus configuration was the difference in the inducer height. We thus examined in this experiment the effect of the inducer height on critical spatial frequency.

3.1. Methods

3.1.1. Subjects

Six naïve subjects different from those in Experiment 1 participated.

3.1.2. Apparatus

The apparatus was the same as that in Experiment 1.

3.1.3. Stimuli

The inducer height was varied from 0.0125 to 3.2 deg in octave steps. The gap between the upper and lower gratings was 2.4 deg. The other stimulus conditions were the same as those in Experiment 1.

3.1.4. Procedure

The procedure was the same as that in Experiment 1.

3.2. Results and discussion

Fig. 5 shows that critical spatial frequency was constant over changes in the inducer height. This result shows that the inducer height is not critical to these in-phase completion phenomena, which supports the idea that neon color spreading and photopic phantoms might share the same mechanism.

The result also suggests that the source of the in-phase lightness induction shown by neon color spreading and photopic phantoms might be limited to the vicinity of the border between the inducer and the gap. This characteristic resembles the Craik–O'brien–Cornsweet effect that small luminance modulation given at the border between two regions of the same luminance induces a lightness difference in the same direction as the luminance modulation (Cornsweet, 1970).

4. Experiment 3

The grating induction effect, which is characterized by counterphase lightness induction, has been investigated as a closely related phenomenon to visual phantoms (McCourt, 1982, 1994) (Fig. 3a). However, when the inducer height is shortened, very faint but in-phase lightness induction appears (Fig. 3b). This effect can be attributed to neon color spreading since its lightness induction is in-phase. To examine the turning point from neon color spreading to grating induction, we measured in this experiment critical spatial frequency as a function of the inducer height.

4.1. Methods

4.1.1. Subjects

Six naïve subjects different from those in Experiments 1 and 2 took part.

4.1.2. Apparatus

The apparatus was the same as that in Experiment 1.

4.1.3. Stimuli

The highest and lowest luminances of inducing gratings were 47.65 and 2.30 cd/m^2 (contrast was 0.91), respectively. The luminance of the background including the gap was 24.98 cd/m^2. The inducer height was varied from 0.0125 to 3.2 deg in steps multiplied by four. The gap was 2.4 deg.

4.1.4. Procedure

The procedure was almost the same as that in Experiment 1. The only difference was that subjects responded to any lightness induction whether they are in-phase or counterphase.

4.2. Results and discussion

Critical spatial frequency increased as the inducer height increased ($F_{4,20} = 9.87$, $P < 0.01$) (Fig. 6). The turning point seems to be around 0.2 deg in height. This result shows that grating induction gives higher critical spatial frequencies than does neon color spreading, being consistent with prior results that showed grating induction magnitude to increase with inducing grating height (McCourt, 1982; Foley & McCourt, 1985).

In addition, there was no significant difference in critical spatial frequency between neon color spreading in this experiment (the condition of 0.0125 deg of the inducer height) and neon color spreading in Experiment 1 or 2. This result supports the idea that the very faint in-phase lightness induction seen in Fig. 3 is a variation of neon color spreading.

5. Experiment 4

Experiment 3 showed that the turning point from neon color spreading to grating induction was 0.2 deg in the inducer height. However, the measure was critical spatial frequency, not the lightness induction itself. We thus examined in this experiment the turning point by measuring lightness induction with a cancellation technique.

5.1. Methods

5.1.1. Subjects

Five naïve subjects different from those in Experiments 1–3 took part.

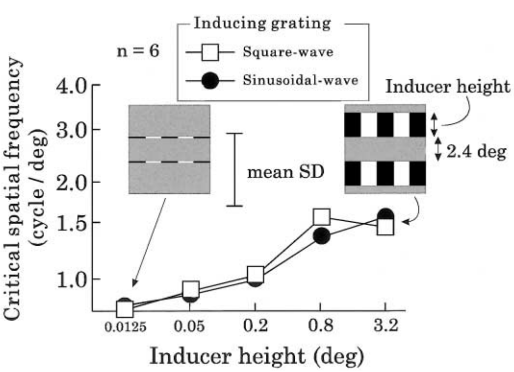

Fig. 6. Critical spatial frequency as a function of the inducer height when luminance conditions favor grating induction. Critical spatial frequency increased as the height increased. The turning point might be around 0.2 deg of the height. There was no significant difference between sinusoidal-wave and square-wave inducing gratings.

5.1.2. Apparatus

The apparatus was the same as that in Experiment 1.

5.1.3. Stimuli

The gap was modified with a cancellation stimulus, which consisted of a sinusoidal-wave (or square-wave) vertical grating, in-phase or counterphase with the inducing sinusoidal-wave (or square-wave) gratings. The smallest step of luminance amplitude changes for cancellation was about 0.007 cd/m^2. The average luminance of the cancellation grating was the same as the luminance of the background. The inducer height was varied from 0.0125 to 0.4875 deg in steps multiplied by about 2.5. The other stimulus conditions were the same as those in Experiment 3.

5.1.4. Procedure

When subjects pressed upward or downward arrow keys, contrast of the cancellation grating was changed accordingly. Their task was to cancel the induced lightness by using the cancellation grating. The initial contrast of the cancellation grating, in-phase or counterphase randomly chosen, was large enough to perceive the lightness modulation clearly. For obtained data, positive values mean in-phase cancellation or indicate that the lightness induction was counterphase, while negative values mean counterphase cancellation or indicate that the lightness induction was in-phase. Data were converted to percent cancellation amplitude, which is defined as: (luminance amplitude of the cancellation grating/luminance amplitude of the inducing grating) $\times$ 100. The other parts of procedure were the same as those of Experiment 3.

5.2. Results and discussion

Lightness induction was slightly in-phase when the inducer height was small, whereas induction was counterphase when the height was large ($F_{4,16} = 24.44$, $P < 0.01$) (Fig. 7). The turning point seems to be around 0.075 deg in height, suggesting that grating induction might require the inducer height of about 0.075 deg. This value is lower than 0.2 deg obtained in Experiment 3. Combining the values in Experiments 3 and 4, here we take an intermediate value 0.1 deg as the turning point.

When the inducer height was large and counterphase induction was dominant, sinusoidal-wave inducing gratings produced a greater induction than square-wave gratings (interaction: $F_{4,16} = 10.26$, $P < 0.01$), which replicated the previous result of McCourt (1982).

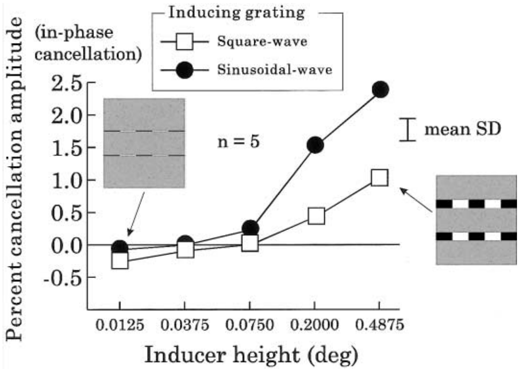

Fig. 7. Percentage cancellation amplitudes as a function of the inducer height when luminance conditions favor grating induction. Percentage cancellation amplitudes changed from small counterphase cancellation (indicating in-phase lightness induction) to large in-phase cancellation (showing counterphase lightness induction) as the height increased. The turning point might be around 0.075 deg of the height. The sinusoidal-wave inducing grating showed significantly larger amplitudes than did the square-wave grating ($F_{1,4} = 78.58$, $P < 0.01$).

6. General discussion

The results of Experiments 1 and 2 show that the tuning curve of critical spatial frequency of neon color spreading was almost the same as that of the photopic visual phantom illusion. It is thus suggested that neon color spreading might share the same mechanism as photopic phantoms.

This suggestion is of great interest from the viewpoint of visual phantoms since several variations of phantoms have been found and discussed. They include, other than photopic phantoms (characterized by in-phase lightness induction) (Kitaoka et al., 1999), scotopic phantoms (characterized by counterphase lightness induction) (Gyoba, 1983), second-order phantoms (characterized by contrast-modulated feature induction) (Gyoba, Sasaki, & Sakurai, 2000), random-dot motion phantoms (characterized by motion completion) (Tynan & Sekuler, 1975) and our unpublished variations of phantoms (depth phantoms, etc).

The results of Experiments 3 and 4 show that the critical inducer height that separates neon color spreading from grating induction is around 0.1 deg. This small size might reflect receptive field sizes of V1 cells (Dow, Snyder, Vautin, & Bauer, 1981; Van Essen, Newsome, & Maunsell, 1984). We thus assume that grating induction might be based on elongated V1 cells that selectively respond to the orientation of inducing gratings (Foley & McCourt, 1985), whereas neon color spreading as well as photopic phantoms would be based upon cells that signal only the vicinity of the border between the inducer and the gap. The cells responsible for the latter could be orientation-selective neurons or cells that have circular receptive fields, and their outputs might be intergrated or modulated by long-range connections that have been revealed to play an important role in global contour formation and surface segmentation (Levi, 1999; Spillmann, 1999; Gilbert, Ito, Kapadia, & Westheimer, 2000).

In this relation, it might be possible that high-frequency channels underlie in-phase induction, while low spatial channels sponsor counterphase induction (McCourt & Blakeslee, 1993). One of the referees pointed out a phenomenon that the magnitude of grating induction slightly increased when the edges between the inducing grating and the test field (= occluder) were blurred (McCourt & Blakeslee, 1993) and imagined that this effect could be explained by our claim that the vicinity of edges is really responsible for in-phase induction.

Photopic phantoms are most vivid when the contrast of the inducing grating is low (Kitaoka et al., 1999), whereas neon color spreading does not show such a constraint (Van Tuijl, 1975; Van Tuijl & de Weert, 1979). Here, we speculate that in-phase lightness induction rapidly saturates when the contrast of the inducer is increased, while counterphase lightness induction is linearly enhanced by the increase in contrast up to some much higher saturation level (McCourt & Blakeslee, 1994). According to this speculation, high-contrast gratings would increase counterphase lightness induction in the figure of photopic phantoms and the produced counterphase induction competes with the in-phase lightness induction, resulting in cancellation. However, the figure of neon color spreading does not produce counterphase lightness induction because of its small inducer height, thus being robust over changes in contrast.

In summary, it is suggested that neon color spreading and photopic visual phantoms should belong to a common class of in-phase completion phenomena and be mediated by the same neural mechanism that contains the source of in-phase lightness induction in the vicinity of the border between the inducer and the gap. However, it is suggested that the source of counterphase lightness induction might be orientation-selective V1 cells that respond to the orientation of inducing gratings.

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References

Anderson, B. L. (1997). A theory of illusory lightness and transparency in monocular and binocular images: the role of contour junctions. *Perception*, *26*, 419–453.

Bressan, P., Mingolla, E., Spillmann, L., & Watanabe, T. (1997). Neon color spreading: a review. *Perception*, *26*, 1353–1366.

Cornsweet, T. (1970). *Visual perception*. New York: Academic Press.

Dow, B. M., Snyder, A. Z., Vautin, R. G., & Bauer, R. (1981). Magnification factor and receptive field size in foveal striate cortex of the monkey. *Experimental Brain Research*, *44*, 213–228.

Foley, J. M., & McCourt, M. E. (1985). Visual grating induction. *Journal of Optical Society of America*, *A*, *2*, 1220–1230.

Genter, C. R. II, & Weisstein, N. (1981). Flickering phantoms: a motion illusion without motion. *Vision Research*, *21*, 963–966.

Gilbert, C., Ito, M., Kapadia, M., & Westheimer, G. (2000). Interactions between attention, context and learning in primary visual cortex. *Vision Research*, *40*, 1217–1226.

Gyoba, J. (1983). Stationary phantoms: a completion effect without motion and flicker. *Vision Research*, *23*, 205–211.

Gyoba, J., Sasaki, H., & Sakurai, K. (2000). Visual phantoms can be produced by second-order gratings. *Investigative Ophthalmology & Visual Science*, *41*, S228 Abstract no. 1198.

Kitaoka, A., Gyoba, J., & Kawabata, H. (1999). Photopic visual phantom illusion: its common and unique characteristics as a completion effect. *Perception*, *28*, 825–834.

Kitaoka, A., Gyoba, J., Kawabata, H., & Sakurai, K. (in press) Perceptual continuation and depth in visual phantoms can be explained by perceptual transparency. *Perception*.

Levi, D. (1999). Editorial: long range interactions in vision. *Spatial Vision*, *12*, 125–127.

McCourt, M. (1982). A spatial frequency dependent grating-induction effect. *Vision Research*, *22*, 119–134.

McCourt, M. (1994). Grating induction: a new explanation for stationary phantom gratings. *Vision Research*, *34*, 1609–1617.

McCourt, M. E., & Blakeslee, B. (1993). The effect of edge blur on grating induction magnitude. *Vision Research*, *33*, 2499–2507.

McCourt, M. E., & Blakeslee, B. (1994). Contrast-matching analysis of grating induction and suprathreshold contrast perception. *Journal of Optical Society of America*, *A*, *11*, 14–24.

May, J. G., Brown, J. M., & Roberts, S. (1999). Afterimages, grating induction and illusory phantoms. *Vision Research*, *39*, 3025–3031.

Redies, C., & Spillmann, L. (1981). The neon color effect in the Ehrenstein illusion. *Perception*, *10*, 667–681.

Redies, C., Spillmann, L., & Kunz, K. (1984). Colored neon flanks and line gap enhancement. *Vision Research*, *24*, 1301–1309.

Rosenbach, O. (1902). Zur Lehre von den Urtheilstauschungen. *Zeitschrift für Psychologie*, *29*, 434–448.

Spillmann, L. (1999). From elements to perception: local and global processing in visual neurons. *Perception*, *28*, 1461–1492.

Tynan, P., & Sekuler, R. (1975). Moving visual phantoms: a new contour completion effect. *Science*, *188*, 951–952.

Van Essen, D. C., Newsome, W. T., & Maunsell, J. H. R. (1984). The visual field representation in striate cortex of the macaque monkey: asymmetries, anisotropies, and individual variability. *Vision Research*, *24*, 429–448.

Van Tuijl, H. F. J. M. (1975). A new visual illusion: neonlike color spreading and complementary color induction between subjective contours. *Acta Psychologica*, *39*, 441–445.

Van Tuijl, H. F. J. M., & de Weert, C. M. M. (1979). Sensory conditions for the occurrence of the neon spreading illusion. *Perception*, *8*, 211–215.