Journal of Illusion

PHENOMENAL REPORT

Motion-induced blindness occurs with a simple motion mask

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Abstract

We present a series of visual illusions, in which a stationary target composed of three dots can be erased in front of the viewer's eyes by employing a limited number of stimuli moving near or behind the targeted dots. The simplicity of the configurations, including the target and moving stimuli, provides insights into the conditions that are necessary to achieve motion-induced blindness.

Keywords: *MIB*; *dot disappearance*; *grouping*; *gestalt*; *proximity*; *collinearity*

To access the movies for this article, please visit the article landing page or read the HTML version if the paper where all moves are embedded

Edited by:
Takahiro Kawabe, NTT Communication Science Laboratories, Japan

Reviewed by:
William Stine, University of New Hampshire, USA

Alexander Pastukhov, University of Bamberg, Germany

Received: 23 April 2023; Revised: 12 July 2023; Accepted: 22 October 2023; Published: 08 February 2024

In 2001, Bonneh et al. reported a visual illusion called motion-induced blindness (MIB), which continues to be of interest to vision researchers. This phenomenon involves the suppressed perception of a set of salient stationary dots (i.e. target) in the periphery of the visual field by moving a global dot pattern (i.e. stimuli) around the target. To date, many important findings have been reported regarding the spatiotemporal relationships among stimuli and targets that induce MIB (e.g. Gorea & Caetta, 2009; Graf et al., 2002; Hsu et al., 2006; Kawabe et al., 2007; Mitroff & Schol, 2005; New & Scholl, 2008; Scholvinck & Rees, 2009), but the core conditions of the phenomenon are not fully explained. This might be attributable to the fact that the disappearance phenomena are essentially spontaneous or stochastic, and thus, the space and time of their occurrences are strictly unpredictable or uncontrollable.

Here, we report simpler stimulation methods than those developed by Bonneh et al. because the number of dots used as motion stimuli is minimized. Using movies, we show that a great number of moving dots is not necessary to induce the disappearance of a target composed of stationary dots. Simplifying the spatial relationships among two types of dots can provide insight into the MIB phenomenon.

The target configuration we use is similar to Bonneh et al., in which a yellow dot is placed at each vertex of a hypothetical equilateral triangle (e.g. Movie 1). Blue dots of the same size as the target dots are used as motion stimuli. Seeing the target, our viewers reported that the spatial pattern of three yellow dots gives rise to their subjective impression of an equilateral triangle, even though no lines or edges exist between three yellow dots.

In our laboratory, the viewers sat in front of the PC monitor at his or her eye level with a viewing distance of 0.56 m. In all tasks, they fixated on the red cross, subtending 0.52°in the center of the target pattern, using both eyes. Both the target and stimuli consist of dots, displayed on a black background (luminance level of 0.34 cd/m^2) with luminance levels of 222.90 and 20.28 cd/m^2, respectively. The visual angle of three yellow dots was 8.50°with respect to the fixation point. The large and small circular orbits on which each of the three blue dots moved were set 0.75° outward and 0.85° inward relative to the yellow dots, respectively.

In Movie 1, of the six blue dots, one set of three blue dots rotates counterclockwise on an outer circular orbit of the yellow dots, while the other set of three blue dots rotate clockwise on an inner circular orbit of the yellow dots (see panels *a* to *d*). The two sets of blue dots begin rotating simultaneously at the same angular velocity

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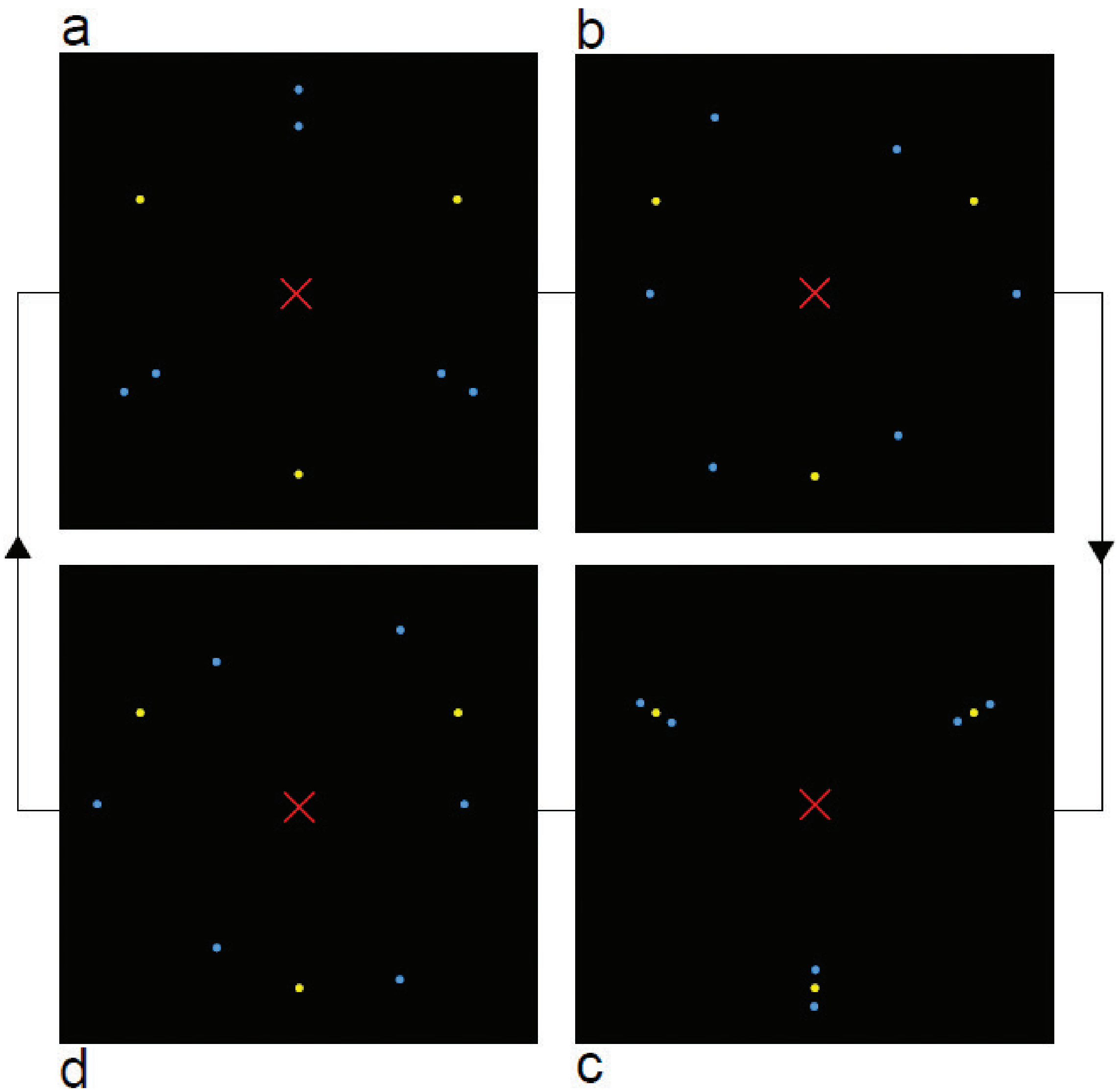
Citation: Journal of Illusion 2024, **5**: 9623 - https://doi.org/10.47691/joi.v5.9623



Movie 1. Time-varying configurations of stationary dots and moving stimuli. Four panels (a) to (d) show the spatial pattern and cycle of the blue dots. In all panels, three yellow dots compose a common stationary target. When each pair of three blue dots moves from the start position in (a) to a location one-sixth of the way around the circumference (c), two blue dots are radially aligned with each yellow dot. Then, by moving a further one-sixth of the circumference, the blue dots recover their original configuration (a). For details, see the text.

but in opposite directions from the position in panel *a*. While the blue dots are rotating, the viewers maintain a fixed gaze on a small red cross in the center of the monitor.

Soon after the rotation begins, the viewers notice that the yellow dots simultaneously disappear when two blue dots approach and flank each one of the yellow dots in three local areas (panel *c*). More precisely, when three dots align on a hypothetical straight line originating from a viewer's gazing point, or when both the degree of *proximity* and *collinearity* of three dots reaches its maximum, the yellow dots disappear. After one second or more, the missing yellow dots become visible again.

Movie 2 is set up so that all the blue dots used in Movie 1 move on a circular orbit of a similar radius as the yellow dots, such that all of the blue dots have moments of spatial overlap with yellow dots during their rotations. Since the blue dots are behind the yellow dots at the moment of overlap, they do not erase the yellow dots physically. Nevertheless, the viewers see the yellow dots disappear at this moment. When this occurs, nothing is visible because the blue dots are behind the yellow dot being erased. Similar to Movie 1, one or more yellow dots, or frequently all three dots, disappear synchronously for more than one second. Shortly after this, the visibility of the blue dots is recovered earlier than that of the yellow dots.

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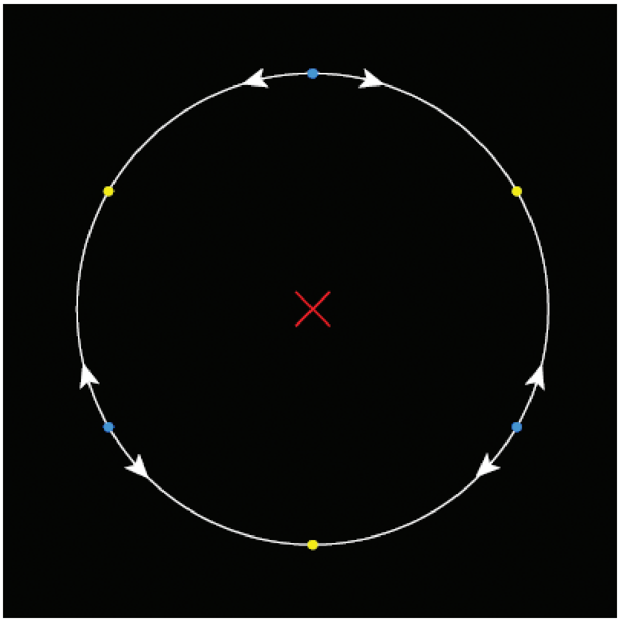


Movie 2. The movement pattern of six blue dots on a common circular orbit. The number of moving blue dots and stationary yellow dots are both the same as in Movie 1, except that pairs of blue dots are perfectly overlapped and seen as one in each of three positions. The six blue dots start to move in the directions indicated by the arrow heads at the same time. Since the orbits of all the blue dots are unified into a single circular orbit (see a while, hypothetical circular path) whose radius is equal to that of yellow dots, blue dots move in opposite directions and overlap behind the yellow dot positions, simultaneously. For further details, see the text.

Movies 3a and 3b show how reducing the number of blue dots affects the number or pattern of disappearance of the three yellow dots. In Movie 3a, the blue dots line up with yellow dots in two locations, instead of three in Movie 1. In Movie 3b, since the number of blue dots is two, they align with one of the three yellow dots at a time. In both movies, the flanked yellow dots vary with different pairs of blue dots. Surprisingly, in Movie 3a, at the moment the blue dots radially line up with the two yellow dots, not only the corresponding yellow dots but the remaining one disappears at the same time. Similarly, in Movie 3b, when the two blue dots flank one of the three yellow dots not only the corresponding yellow dot but also the other two disappear, nearly simultaneously.

In both movies, some viewers may report that although the disappearance of a yellow dot flanked by two blue dots holds true, the other yellow dots are still visible. Nevertheless, with repeated trials and steady fixation, the frequency of simultaneous disappearance of three yellow dots gradually increases over time. The disappearance of a local yellow dot, which occurs when it is flanked by a pair of blue dots, appears to link to the disappearance of the other yellow dots that are spatially distant.

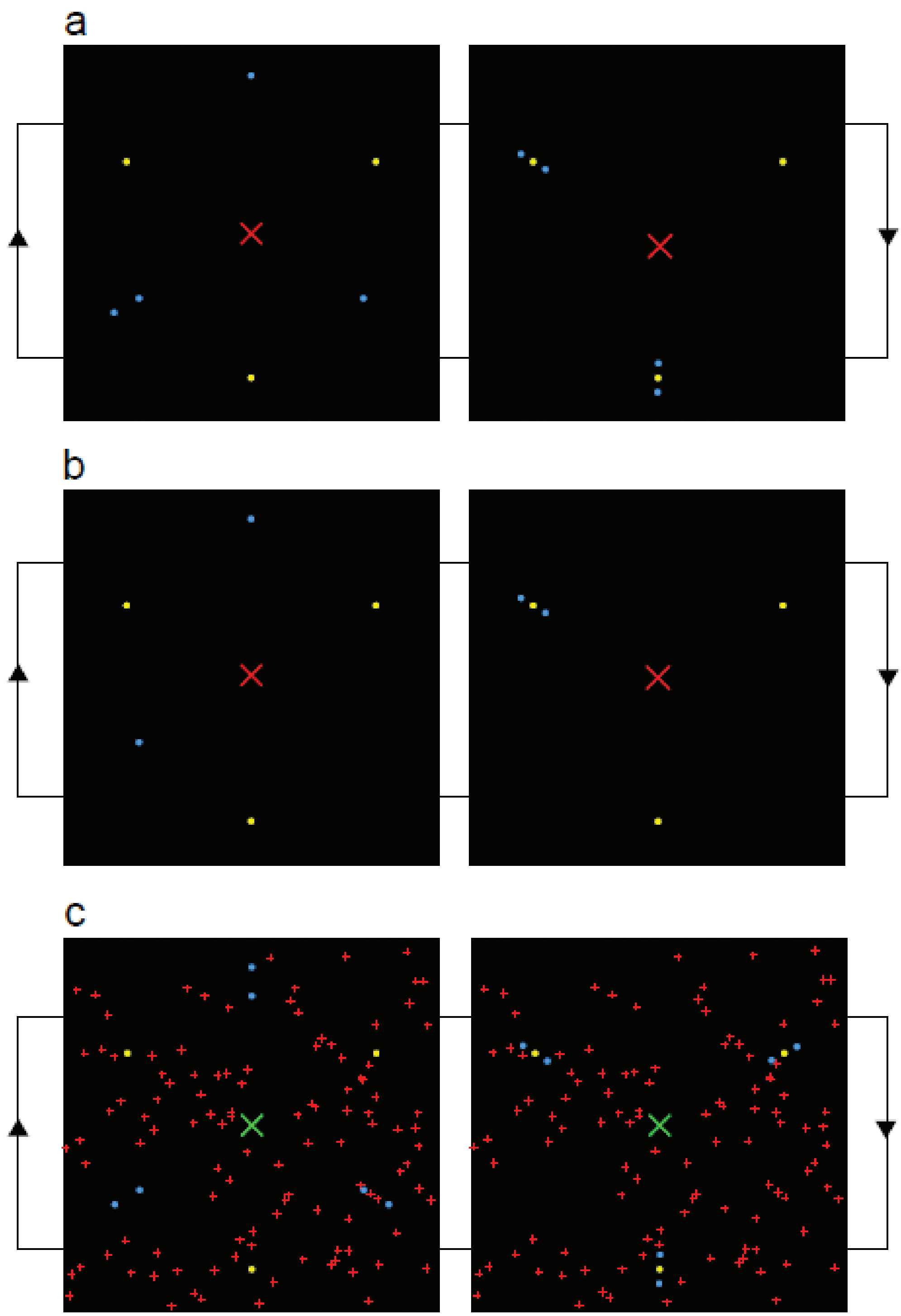
Furthermore, supplementary Movies 1s and 2s confirm the linked disappearances of the non-flanked dots, when the same two dots or one dot are repeatedly flanked. In Movies 1s and 2s, the synchronized disappearance of non-flanked dots with the disappearance of the flanked dots is observed as frequently as that in Movies 3a and 3b, suggesting that the difference in the manner of stimulus presentation does not have profound effects on the linked disappearances of flanked and non-flanked dots.

Movie 3c confirms the target specificity of the disappearance of yellow dots, where the target and moving stimuli are both displayed in front of a noisy background composed of 200 hundred stationary and randomly placed red crosses, similar in size to the yellow dots. The number of blue dots and their pattern of motion are the same as those in Movie 1. When two blues dots radially line up with each yellow dot in all three local positions, the yellow dots selectively disappear, independently from the sustained visibility of many red crosses. However, some viewers may report that the sustained visibility of all red crosses is imperfect, because those close to the yellow dots may seem to disappear along with the yellow dots. To this point, it can be said that the majority of red crosses remains visible independently of the stimulus-induced disappearance of the targeted dots, implying that the disappearance of the targeted dots is not due to the simultaneous suppression of vision over an entire visual field.

Discussion

By minimizing the number of blue dots that serve as motion stimuli, an instantaneous geometry among them and the disappearing target (i.e. three yellow dots) becomes more distinct in two respects, locally and globally. On the local level, when a yellow dot is flanked by two blue dots in the radial direction (Movies 1, 3a, and 3b) or when the yellow and blue dots overlap (Movie 2), the corresponding yellow dots disappear. On the global level, when some yellow dots disappear because of flanking, as described above, the other yellow dots tend to disappear nearly synchronously (Movies 3a and 3b).

On the local level, the disappearance of a single yellow dot, which occurs when it is flanked by a set of two blue dots in all movies, might be related to changes in the meaning of its presence, as if it is switched from one identity to another. For example, in either of the three local positions, when a yellow dot is flanked by two blue dots, the presence of the corresponding yellow dot may be transformed from being a part of the three yellow dots when viewed globally to being one of the three dots that are momentarily grouped side by side in a local location. At this point, *collinearity* or *proximity*, as defined by Gestalt psychology, may be an important factor in bringing about groupings of parts in local space. Under this speculation, the disappearance of yellow dots in the local



Movie 3. Two configurations of stationary dots and moving stimuli. (a) When the number of blue dots is four. The left and right panels show positions of all dots when the blue dots start to move and when three dots become aligned in two radial directions, respectively. Notice that the number of blue dots is reduced to four, thus their displacement along one-sixth of the circumference leads to the radial alignment with two of the three yellow dots. The yellow dots flanked by blue dots are changed on a trial-by-trial basis. For details, see the text. (b) When the number of blue dots is two. The left and right panels show the positions of the dots when the blue dots start to move and when three dots become aligned in one of the three radial directions, respectively. The number of blue dots is reduced to two, thus their displacement along one-sixth of the circumference results in radial alignment with one of the three yellow dots. The yellow dot flanked by two blue dots is changed on a trial-by-trial basis. For details, see the text. (c) In a random dot field. The configurations of all dots are similar to those used in Movie 1, and they are represented in the far field of viewers' eyes. The spatial patten of a random dot field, represented by a number of small red crosses, is changed when blue dots move every one-third of a circumference. For details, see the text.

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space might be a phenomenon related to the generation of a new identity.

On the global level, it is important to notice what was described by Bonneh et al. (2001). They tested the disappearance of a whole object composed of dots or line segments (see Figs. 3 and 4 in Bonneh et al.), and found that the parts that are perceptually grouped into a coherent whole, or Gestalt, tend to disappear and reappear in a coherent fashion (see also Devyatko & Pastukhov, 2018; Mitroff & Schol, 2005; Montaser-Kouhsari et al., 2004; Shibata et al., 2010). In other words, if there is a certain wholeness in the spatial arrangement of parts, partial loss of the parts, which is caused by the background moving stimuli, expands to all the parts composing a whole. In considering why the non-flanked dots disappeared in Movies 3a and 3b, the cause of the phenomenon might be attributable to geometric specificity of dot pattern, composing one identity, a triangle.

To confirm this, another important factor of grouping, which has not been described by Bonneh et al., is necessary. That is, *similarity* in the shape, color, and size of parts helps to group them under a single identity. In Movie 3c, three yellow dots are selectively erased in the presence of a noisy background, suggesting that they are grouped into an independent identity from the background. Moreover, as shown in Movies 3a and 3b, the disappearances of yellow dots flanked by blue dots appear to propagate to the non-flanked yellow dots. This might be attributable to the *similarity* among parts as a negative effect on a grouped presence of parts, meaning that a partial loss of the grouped parts (i.e. a dot) propagates to other parts, causing the whole group to disappear.

Notably, at the instant the dots partially erased by flanking, the perceptual continuity of seeing the same object in a global dot pattern is apparently disrupted, and correspondingly, the pattern of bindings among the remaining dots may be switched into that composing a new object. According to this scheme, the visual system must swiftly cancel the representation of the previous identity, because two identities cannot coexist on the conscious level. That is, to assign a new identity to the altered pattern of dots, it is necessary to abandon the previous identity as a whole, even if the new one partly shares the same dots with the previous one. The disappearance phenomena reported here may reflect this change in object identity, leading to the simultaneous disappearances of all parts composing a prior identity.

The grouping of parts appears to be an inherent, inevitable process associated with object recognition and identification (Wagemans et al., 2012). If so, the visual disappearance of an entire object might not be explained by the suppression of signal propagation in the retina close to the input or in the lower brain processing but by a simultaneous suppression of an object-based representation in the higher centers. Our findings on visual disappearance, which can be controlled using a limited number of moving dots, suggest that a partial or local deficit of some geometric factor that maintains the grouping among composite parts induces the visual disappearance of a coherent whole.

Acknowledgments

The authors would like to thank all of the laboratory members for their feedback on this work.

Conflict of interest and funding

The author declares no competing financial interests. The authors have not received any funding or benefits from industry or elsewhere to conduct this study.

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