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PHANTOMS AT THE HOLIDAY INN

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ARVO is a vision conference, now superseded by VSS (the Vision Sciences Society), but like VSS it was originally held in Florida at a beach front hotel. The current ARVO is a staid affair, having drifted away from Florida and its original mission, and now attended mostly by ophthalmologists, but in its early era it was an interdisciplinary hot bed of vision research, wildly successful undoubtedly because of its location on beautiful white sand beaches. In 1977, it was the first vision conference I attended and I was doing my best to keep up and make sense of the flood of new ideas and excitement. The meeting room was a Holiday Inn conference venue perched on the Lido Key beach facing the Gulf of Mexico. Much of our day, at least noon to 4 pm was spent on that beach talking and playing but now, later in the day, we were on the top floor of the hotel and the room was packed to hear Naomi Weisstein. This was not science as I knew it. Her talk was punchy, full of jokes and new ideas about visual cognition, phantoms, and a demonstration. A show-stopping demonstration. Off went the room lights and up came a movie (no videos at that time) of vertical strips of Xs interrupted in the middle by a dark horizontal band (Figure 2.1). "Look at the way the light and dark bars complete across the strip," she said, and there was a murmur of agreement. Magical phantoms crossed the gap, which I learned later had been previously reported (Tynan & Sekuler, 1975). But forget that, Naomi was telling us that not only were there phantoms, but they also generated motion aftereffects in the gap where nothing had been present. These findings were reported in December of that year in a *Science* paper (Weisstein et al., 1977).

On the left is an original frame digitized from the 1977 demonstration movie with arrows overlaid to indicate the motion (see Movie 1 in the list at end of chapter). In the center is a close up depiction of what the authors, Weisstein, Maguire, and Berbaum (1977) claimed they and their observers saw – light and

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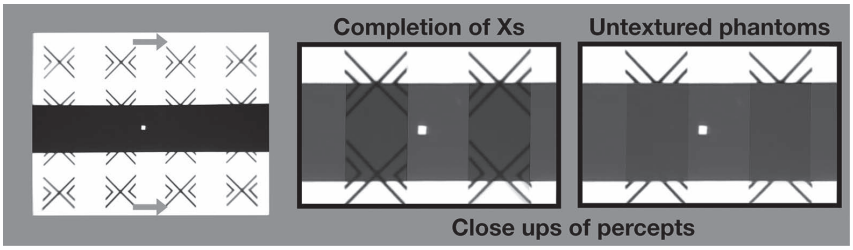

FIGURE 2.1 Phantom texture completion.

dark bars completing across the gap in the same phase as the moving stripes but importantly with a faint continuation of the X pattern. The contrast of the induced patterns is exaggerated here. On the right is a close up of what most would agree is visible when the grating moves – the phantom stripes but without any texture completion. The contrast is again exaggerated compared to what observers actually see. This chapter chronicles my efforts to track down the elusive extrapolating Xs.

Back in the presentation hall, oohs and aahhs started gradually and then were overwhelmed by another commotion as she said that some of us should also see the Xs complete through the gap. I believe I remember seeing them. Clearly some others did as well, because several called out for her to stop the projector on a single frame to prove there was no trickery. "Stop the projector!" The projectionist stopped the movie on a single frame – there were no Xs in the gap. "Start it again!" The movie clattered into action and there were the Xs again, at least for some of us. Enough to get a good measure of applause.

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That was my introduction to the immediacy and excitement of the new vision science. It was a special moment when physiology and computer vision and psychophysics were joining together to find new questions, answers and models. Fourier theories were in the air. Crackling presentations by Bela Julesz, Stuart Anstis, David Marr, John Robson, Richard Gregory, and Naomi made us feel like the best and smartest were converging on vision science as the gateway to a new understanding of the brain. We were getting high on science. Naomi herself was bursting with charisma and confidence and intelligence. She chortled with each point she made, "hah", like the fist pumps that tennis players make when they baffle an opponent. But sports players are rather humorless (except for Spaceman Bill Lee, the legendary pitcher of the Montreal Expos) whereas Naomi had humor in abundance.

As you can judge from my retelling, Naomi's talk was imprinted on my new vision scientist's mind as an astounding finding opening new directions and I have spent numerous moments in the last 40 years tracking it down. In their *Science* paper they reported the extrapolating Xs in only one sentence and spent the rest of the article describing the motion aftereffect they measured on a test placed in

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the unstimulated gap. Even so, they were very confident of the effect. Naomi even told Bob Sekuler that not just Xs would complete into the gaps. If she had put birds in the columns instead of Xs, she said, we would not only see birds in the gap but we could also report what kind of bird it was.

However, in our ordinary labs, it was not evident that any Xs, let alone birds, would ever appear in the staunchly black occluding stripe. Yes, we could see the phantom stripes of light and dark faintly crossing the gap but they were quite dim and always untextured. Our first attempts with Peter Tse, 15 years after the ARVO presentation, used regular computer controlled video. This failed to generate any texture completion and we thought it might be the differences in the properties of the monitors compared to the movie. Or perhaps we had all been simply in the thrall of Naomi's wonderful presentation skills and had undergone a mass induction. Naomi and her colleagues and Sekuler published other papers on this moving phantom grating effect (Brown & Weisstein, 1988, 1991; Brown, 1993; Mulvanny et al., 1982) but there were no further tests of the texture completion with moving gratings. In Japan, Akiyoshi Kitaoka, Jiro Gyoba, Hideaki Kawabata, and Kenzo Sakurai explored many versions of static gratings that produced phantoms but without any texture completion (until recently, see their chapter in this book). What was up? Was there nothing here? But first, why was Naomi's claim of pattern extrapolation interesting anyway?

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When a pattern is partially hidden, we do represent the missing parts behind the occluding surface, or at least our brain does, somewhere. When we see a dog's head sticking up behind a garden gate, for example, we do not take it as an unattached head; instead, our visual system represents the missing body. But importantly we do not see or hallucinate the missing body as if it were visible through the door—it has a more abstract, non-visual representation. The phantom grating, originally reported by Tynan and Sekuler (1975), is an exception. If the occluded pattern is moving and present on both sides of the occluder, it is no longer just represented notionally as going behind the gap but completes in front as if it were a dim transparency that is sliding over the occluder. Perhaps it is just easier to have some visible token that is moving rather than continually updating an invisible, hidden token. We really do not know why this happens, but the important part, at least to start, is that the phantom is visible and it gives an observable percept to help explore and understand these completion processes.

Naomi made the completion do work, by showing a motion aftereffect in the physically unstimulated central portion. But we want to do more. What patterns would complete? How detailed would they be? Would fMRI show activation to the patterns in the gap? If different patterns or colors were on opposite sides of the gap, would there be a transition from one to the other cross the gap as happens in apparent motion between dissimilar stimuli? Kitaoka, Gyoba, and Sakurai (2006) showed a related chimeric completion of static, fuzzy, untextured vertical bars across a grey occluder when the top background was black and the bottom

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was a random dot pattern. If the vertical bars had texture elements would they too bridge the gap? If they were, say, Xs on top and Os on the bottom, what would the intermediate phantom texture elements look like? Answers to any of these questions would help understand how vision fills in and completes patterns from partial input and where this critical step happens in the various stages of processing in the visual system.

This filling in is of course not the only example we have of completion. Perhaps the most famous is completion across the blind spot where textures and lines and colors complete across the gap where there is no sensory input (see review Ramachandran, 1992). Similar reports are found for other losses of sensory input, scotomas, caused by retinal or cortical damage. However, the nature of the completion, at least for the blind spot, is problematic. Everyone agrees that they see no gap in the blind spot but because it is in peripheral vision it is hard to say whether anything is actually visible there. It might be just a case of thinking the pattern must be filled in because there is no signal to say it is not. Whatever your opinion on this philosophical issue, the practical problem is that the area of the visual field translates to only a small portion of cortex so it is hard to use fMRI to examine what representation there is at that location.

And this is the importance of Naomi's phantom textures. They are right in the fovea and should fill substantial cortical real estate that would offer lots of signal in fMRI. Here again though, there has not been much success. Meng, Remus, and Tong (2005) were able to get phantom contours to cross a gap in the middle of a drifting sinewave grating and they could decode the presence of the induced activation in the cortical areas that respond to the gap where there was no physical stimulus. But they did not find any texture completion across the gap (personal communication, Ming Meng, 2017).

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Perhaps the lack of success in all the follow-up attempts was due to the difference between video and movies. To check this, I wanted to duplicate Naomi's projection version and began an effort to recreate the 1977 event. In 2004, I asked Naomi to send me the actual 16 mm film version she had used. She promptly did. I am not sure how she had uncovered it in the various boxes or files that she had kept over the years, but here it was in my hands. Unfortunately, I couldn't get a 16 mm projector through the audio visual services. They no longer had any. Not unreasonable considering that no one had used 16 mm films in classes for maybe 20 years. I spent the next 10 years pursuing other projects. I moved to Dartmouth in 2015 where again I could not obtain any projector from the audio visual services but finally I bid on one on eBay and won it. It arrived in the summer of 2016 and we quickly tried a screening of the movie. There was a lot of mechanical clattering and the jumping film spewed onto the floor before we learned how to properly thread and maintain the forward progress of the film. I think it is a good thing that we no longer rely on 16 mm projectors. But again, disappointment. We saw some grating

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completion but no convincing Xs in the gap and I worried that maybe Naomi had used a better projector or a different viewing distance. My newly acquired 1960s Bell and Howell model had unstable speed and only a 1 blade shutter giving 24 Hz and a 50 percent duty cycle. High end projectors had 3 blade shutters and a flicker rate of 72 Hz.

Without Naomi to goad us on with encouragement and guffaws, the momentum slowed. But did not fade away. Gyoba, Sakurai, and Kitaoka tried further moving versions (see their chapter here) and presented them at conferences. Observers reported something vaguely textured in the gap.

We generated new computer versions, some that even matched the flicker quality of Naomi's movie and distributed them to several hard-core vision scientists for evaluation (see Movie 3 at end of chapter). Many said they saw nothing but some admitted they could be seeing some texture in the gap, not necessarily visible texture but a feeling that something might be there as if a back texture were sliding over a black surface. This was a long way from the original effect which caused such a stir and even farther from the completion of identifiable birds in the gap. So we tried a few last variations.

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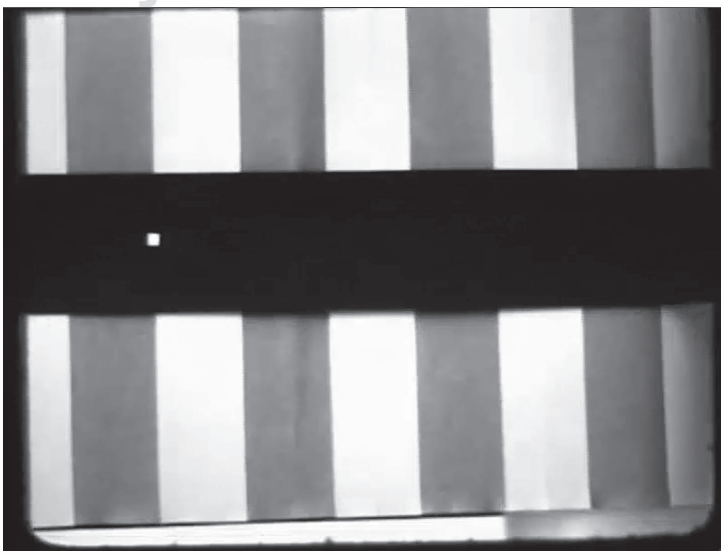

FIGURE 2.2 The scroll of paper with a light and dark grating on it that moved like a conveyor belt around two vertical spindles.

This was the apparatus in the SUNY Buffalo lab that Naomi and her colleagues used to test the phantom gratings, here for simple induction without texture. The dark horizontal strip was a piece of black board spanning the moving display, with a small white fixation mark that was centered in the full display. This version can be seen in Movie 2 (see movie list at the end of the chapter) and produces strong phantom gratings.

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The flicker aspect of the movie version did not turn out to be important and that seems reasonable given that the original tests were run on a set of textured stripes printed onto a scroll of paper that was wound around two drums. Unlike the movie, it was seen in steady light and drifted continuously, powered by a little motor very much like the original devices used by Munsterberg and others to study motion aftereffects at the end of the 1800s and beginning of the 1900s. The apparatus is not described in the article but we can see it in the brief docudrama at the end of Naomi's demonstration movie (Movie 4 below) which records an apparently inadvertent release of the phantoms from the grating. They invade the lab, driving the authors out to the street. We can also see a slight flap at the incompletely glued joint between the two ends of the printed scroll. A horizontal strip of cardboard was positioned in the middle of the grating to create the occluding gap.

Our final tests for this chapter with the movie and the video versions were at a greater viewing distance to mimic the visual angle of the 1977 audience at the back of the hall. Indeed, one skeptical and steely eyed observer felt that the texture was visible spilling across the edges of the occluder but not all the way into its center. The greater viewing distance would narrow the gap in terms of visual angle and perhaps maximize the encroachment of the texture into the gap. The partial completions are the best we have to report and Naomi's original displays were constructed so that the X textures only needed to extend into the gap at the edges (see Figure 2.1 above) – the spacing left only a gap in the middle of the occluder, without room for a full phantom X in the center.

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Naomi's charisma and her stream of novel discoveries – object superiority, phantom gratings, foreground biases, and others – filled a remarkable six *Science* papers (and many others) in the brief span before her illness halted her work. This work brought lots of attention to the new field of visual cognition and we are indebted to her pioneering work in many ways. Many of us who appreciated and followed up on her science were not aware that she was even more famous in two other fields – stand-up comedy and the feminist movement, where she led a feminist rock band on tracks like "Papa don't lay that shit on me". Her feminist writings were so influential that Duke University paid a seven figure amount to get the full catalog of her work, and MS magazine ran a feature article on her. Even if we were unaware of her other selves, we were in no way surprised by her successes in these areas given the drive, wit and creativity that we were so lucky to witness in her scientific presentations.

Movies

To view movies for Chapter 2 go to https://research.franklin.uga.edu/visual-perception-laboratory/chapter-2

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Movie 1 Naomi's original movie. For best results, view at a dim brightness setting in a dark room with nothing else on the monitor (no bright background). Find a viewing location where the image subtends around 5° to 10° of visual angle. Make sure it loops.

Movie 2 Here is the simple light/dark moving grating from the original demonstration movie. I find it produces the best induction of phantom stripes into the gap. I have to block off the grating to convince myself there are not artifacts in the gap. Make sure it loops.

Movie 3 This is a computer generated version of Naomi's movie. Again, for best results, view at dim brightness in a dark room with nothing else on the monitor. You may see some completion of the light and dark stripes across the gap. Some may see some intrusion of the texture into the gap. There is no fixation spot, please add one with the mouse cursor if that helps.

Movie 4 At the end of the 16 mm demonstration film was a quirky, sci-fi docudrama relating what happened in Naomi's lab when the phantoms escaped from the apparatus. Very much in the Beatles "Hard Day's Night" style. The two others in the film are Bill Maguire and Kevin Berbaum, her co-authors of the 1977 paper.

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