Motion perception revisited: High Phi effect challenges established motion perception assumptions

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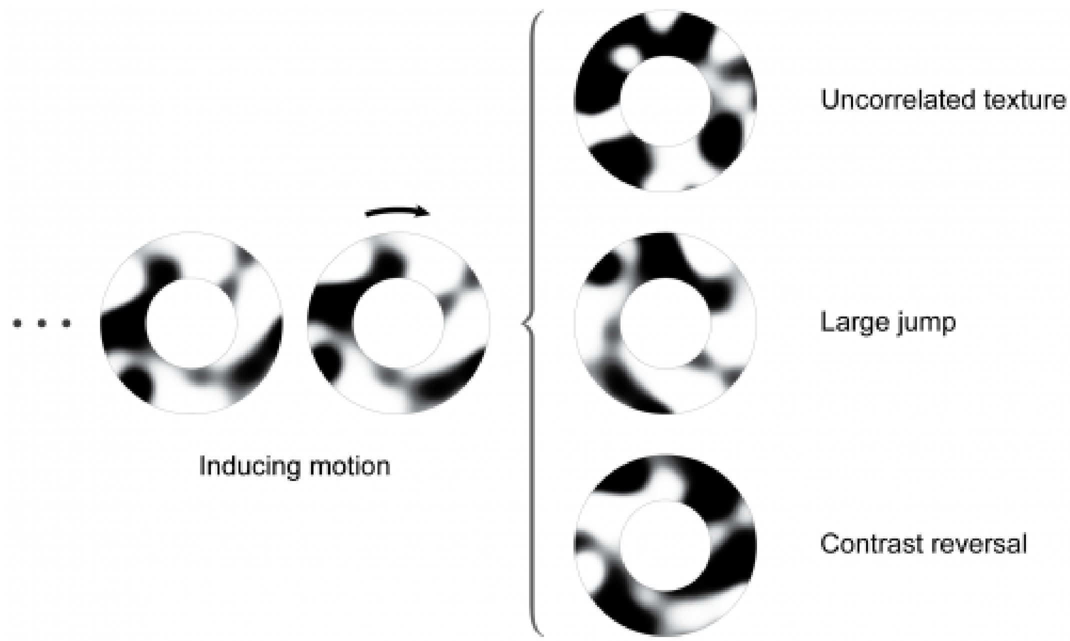

A schematic illustration of the basic high-phi stimuli. Animated versions may be seen in demonstrations 1–4. During the first phase, the inducer, a random texture is slowly rotated, very briefly or for a longer duration. This inducer is followed by the transient, which may be a replacement of the texture by another, uncorrelated random texture (once or several times); a sudden jump of the original texture by an amount large enough that it cannot be detected; or an inversion of the texture contrast. (Other transients also lead to the effect: see text.) The transient leads to the illusory perception of a very rapid rotation, either forward (with respect to the direction of the inducer)—provided the inducer is very brief—or backward—for longer inducers. Copyright © *PNAS*, doi:10.1073/pnas.1213997110

(Medical Xpress)—Optical illusions abound in human visual perception, as demonstrated by the following well-known examples. Although many are static illusions, motion illusions also occur. Recently, scientists at Université Paris Descartes and Centre National de la Recherche Scientifique, Paris, University of Reading, United Kingdom, and Kyushu University, Japan discovered and investigated a new illusory motion effect, termed *high phi* by the authors, in which we perceive conspicuous large illusory jumps when presentation of motion signals are followed by brief visual stimuli free of detectable motion signals. The researchers found that the size of the illusory jump does not depend on the speed of the motion signals presented, but rather on spatial frequency and transient duration while jump duration depends on motion signal duration. The study's authors conclude that their findings demonstrate that existing explanations for this illusion – namely, the loss of coherent motion perception above an upper limit and the preference for minimal motion – are incomplete at best.

Lead researcher Mark Wexler describes some of the challenges he and his colleagues – Andrew Glennerster, Patrick Cavanagh, Hiroyuki Ito, and Takeharu Seno – encountered in conducting their study. "We had the idea that these illusory jumps are related to d_{max}, the supposed upper speed limit on the steps that leads to motion perception, varies between individuals, and must be measured using random textures," Wexler tells Medical Xpress. "For displacements below d_{max} you're supposed to see the motion more or less correctly," he explains, "while for displacement above d_{max} you're just supposed to see noise – and the latter also turns out to be false." (These illusory jumps are demonstrated in an online supplement to the paper.[1])

Interestingly, the researchers discovered the illusion as a bug in a computer program whose purpose was to do something else. "The easy thing to do in those kinds of circumstances is to correct the bug and move on," Wexler comments, "and ignore how strange the effect of the bug actually is. Our key insight was *not* to move on."

According to Wexler, the one finding in motion perception that everyone agrees with, for at least 100 years, is the minimal-motion principle. "The minimal-motion principle states that whenever a stimulus is ambiguous and compatible with more than one motion – as it nearly always is – the brain is supposed to prefer the smallest, slowest motion, including stand-still, that is compatible with the stimulus," he explains. (In fact, he illustrates, many computer vision systems are built around this principle, and neuroscientists have verified it by recording signals from primate neurons.)

"However," Wexler points out, "one consequence of the high phi effect is the minimal-motion principle can be violated! When the stimulus is incompatible with any globally coherent motion, and therefore equally compatible with any motion, people perceive not only a large jump, but the largest possible jump that they can perceive. This maximum jump is the one that steps by d_{max}, which acts as the speed limit on motion perception."

Another principle that seems to be violated by the high phi illusion, according to Wexler, is d_{max} itself. "Below d_{max}, steps should be more or less seen as what they are – and as can be seen in demonstration three, this is what happens. On the other hand, says Wexler, "above d_{max} you're supposed to perceive noise, not motion – but this is *not* what actually occurs." Rather, you perceive the high phi jump, as can also be seen in demonstration three. "In one of our experiments," Wexler adds, "we showed that the amplitude of the jump is very closely correlated with the d_{max} limit, so that people who have higher d_{max} limits also see a larger high phi jump."

It's known, Wexler points out, that the d_{max} limit depends on spatial frequency: the lower the frequency (that is, the larger the features in the stimulus) the higher the limit. "And indeed," he notes, "we found that the magnitude of the illusory jump depends on spatial frequency in exactly the same way: the lower the frequency, the farther the jump." This can be verified, Wexler adds, by viewing high phi demonstration six and demonstration seven.

Discussing the finding that the direction of the jump depends on the duration of the inducing motion signals, Wexler notes, "We think that the preceding – that is, inducing – motion acts like a seed. For brief inducers, the motion itself acts as the seed, and the jump is experienced forwards with respect to the inducer. For longer inducers, vision begins to adapt to the motion – a result known as the motion aftereffect." Also known as the waterfall illusion, the motion aftereffect occurs when, after viewing a moving object for an extended period of time, and that object then becomes stationary, the object appears to slowly move in the opposite direction. "Many people initially think that what we've found is a consequence of adaptation to motion or the motion aftereffect," he says. "If so, then it's the fastest motion aftereffect known. We've measured that the illusory motion is 10-100 times faster than the inducing motion! We think that for motion inducers, the adaptation acts as the seed of the fast, backward jump." (Brief and long inducers can be compared directly in demonstration nine.)

Wexler also describes how their findings relate to the activity of neurons in of the primary visual cortex that respond to lines of a certain angle moving in one direction, as first described by Hubel and Wiesel (1959)[2]. "In the brain, motion detectors are sensitive to motion in a particular place – the receptive field – a particular direction, and usually a particular speed," Wexler notes. "When faced with our stimulus, there can be many accidental matches at the local level. In one image there is a dark spot, for example, and in the next, uncorrelated image there happens to be dark spot just next to it. In that case, a local motion detector will react to this false match – so our stimulus actually activates many local motion detectors, but incoherently, in that all of these motion detectors are signaling different motions. The main point is that in all this incoherent mess the brain finally prefers the largest possible motion."

Commenting on other areas of research that might benefit from their study, Wexler cites computer vision. "The minimal-motion principle is enshrined in a lot of algorithms for extracting motion," he concludes. "Our study shows that this principle can be violated. Can we find a different way to extract motion?"

"The dependence on transient duration – which can be clearly seen in demonstration five – is, to be completely honest, a mystery, but a very interesting one," Wexler continues. "The amplitude of the jump is a very linear function of transient duration, at least for small durations. If some perceptual process goes linearly farther for longer durations, then something in the brain must be effectively rotating at constant speed. I have no idea what that something may be, but it's an interesting challenge for the future."

More information: Default perception of high-speed motion, *PNAS* Published online before print April 9, 2013, doi:10.1073/pnas.1213997110

Related:
[1]Demonstrations of the high phi effect accompanying *Default perception of high-speed motion*
[2]Receptive Fields of Single Neurones in the Cat's Striate Cortex, *The Journal of Physiology* October 1, 1959, 148, 574-591