Perceiving-the-present and a general theory of illusions of projected size, projected speed, luminance contrast and distance

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ABSTRACT

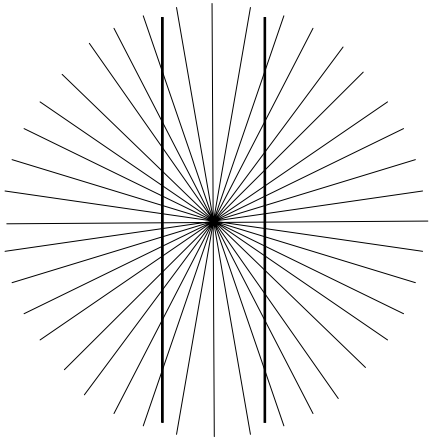
Perceiving-the-present posits that the function of the visual system is to generate percepts representative not of the scene that generated the proximal stimulus, but of the scene that will be present at the time the percept actually occurs about 100 msec later, thereby compensating for the neural delay.

Here we show that perceiving-the-present predicts a particular pattern of illusions over 28 classes of visual stimuli, and we demonstrate that the predicted pattern exists via a meta-review of the literature. That is, the hypothesis explains more than two dozen classes of illusion—and more than 50 subclasses of illusion—and places these diverse classes of perceptual phenomena into a single unified framework.

CLASSICAL GEOMETRICAL ILLUSIONS

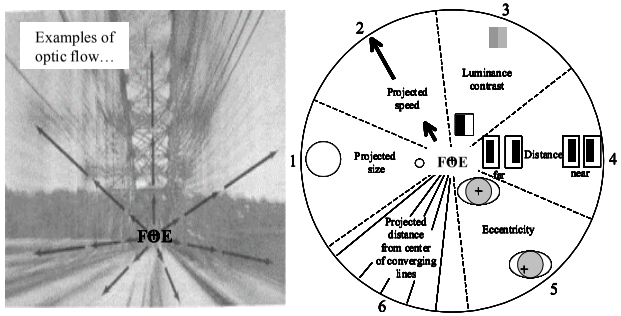
Static geometrical stimuli are consistent with a saccade "snapshot" while in forward motion, where the vanishing point of the converging lines correlates with the observer's direction of motion. This is because of (1) carpentered world, and (2) optic flow blur.

The illusions are consistent with how the lines will project in the next moment if the observer were moving toward the vanishing point.



SIX CORRELATES OF DIRECTION OF MOTION

"Converging lines" is just one of six correlates of direction of motion. The picture below illustrates real world stimuli during forward motion, and the six correlates.



FOUR KINDS OF CHANGE IN NEXT MOMENT

Projected size change is just one of four kinds of change that occurs due to forward motion, where the change depends on where the object is in the visual field relative to the direction of motion.

Projected size, projected speed, luminance contrast, and distance from the observer all change in the next moment depending on where they are in the visual field relative to the direction of motion. For all these features, greater rates of change occur for objects nearer the direction of motion. To understand this, suppose that α and β are identical objects in all respects at time t—i.e., identical projected size, speed, luminance contrast, and distance from the observer. However, suppose that α is nearer to the direction of motion than β. How will α and β differ in the next moment?

(A) The projected size of α will be greater than that of β.
(B) The projected speed of α will be greater than that of β.
(C) The luminance contrast of α will be lower than that of β.
(D) The distance of α will be less than that of β.

⇒ 6×4=24 PREDICTED ILLUSION CLASSES

Six correlates of direction of motion CROSS with four next-moment changes depending on direction of motion, leading to 24 predicted classes of illusion. These predicted classes are shown in the table to the right, with the six along the rows (along with a seventh row for full optic flow), and the four next-moment changes along the columns. Stimuli shown possess cues that direction of motion is toward the left. **Metareview shows that predicted pattern appears to exist.**

A region of the visual field with…	…tends to undergo, in the next moment, (i.e., the predicted perception is of)…			
	(A) **…a greater increase in proximal size (greater decrease in proximal spatial frequency)**	**(B)** **…a greater increase in proximal speed**	**(C)** **…a greater decrease in luminance contrast**	**(D)** **…a greater decrease in distance from the observer**
(1) …lower proximal sizes (greater proximal spat ial freq)…	—**size contrast** (MacKay, 1973; Klein et al., 1974; Georgeson, 1980) —**Ebbinghaus/Titchener illusion** (Massaro & Anderson, 1971; Coren & Girgus, 1978; Weintraub & Schneck, 1986) —**moon illusion** (Kaufman & Rock, 1962; Rock & Kaufman, 1962; Restle, 1970; McCready, 1986; Plug & Ross, 1994; Kaufman & Kaufman, 2000; Redding, 2002) —**nearer horizon ⇒ larger** (Gilinsky, 1955; Leibowitz & Harvey, 1969) —**Oppel-Kundt/Botti illusion** (Oppel, 1854; Lewis, 1912; Rentschler et al., 1981; although counter at high spatial frequency, Rentschler et al., 1981)	—**smaller background features ⇒ faster** (Brown, 1931; Johansson, 1950; Gogel & McNulty, 1983) —**greater dot density of moving object ⇒ faster** (Watamaniuk et al., 1993) —**greater spatial frequency ⇒ faster** (Diener et al., 1976; McKee et al., 1986; although counter at high spatial frequency, Smith & Edgar, 1990) —**smaller patterns ⇒ faster** (Snowden, 1999) —**greater spatial frequency ⇒ less capture ⇒ greater relative speed** (De Valois & De Valois, 1991)	—**greater spatial frequency ⇒ greater "assimilation"** (Helson, 1963; Steger, 1969; Walker, 1978) —**greater spatial frequency surround ⇒ lower contrast** (McCourt, 1982; Yu et al., 2001)	—**smaller surround ⇒ nearer** (Ebbinghaus/Titchener, McCready, 1985) —**horizon moon appears nearer** (Epstein et al., 1961; Boring, 1943, 1962; Rock & Kaufman, 1962; McCready, 1986)
(2) …lower proximal speed…	—**slower ⇒ larger** (Ansbacher, 1944; Virsu et al., 1974; Parker, 1981, 1983; Kaneko & Uchikawa, 1993) —**longer presentation time ⇒ slower** (Katz et al., 1990; Treue et al., 1993) **⇒ lower spatial frequency** (Tynan & Sekuler, 1974; Virsu et al., 1974; Virsu & Nyman, 1974; Kulikowski, 1975; Gelb & Wilson, 1983; Maddess & Kulikowski, 1999)	—**motion contrast** (Loomis & Nakayama, 1973; Walker & Powell, 1974; Tynan & Sekuler, 1975)	—**lower speed surround ⇒ lower contrast** (Takeuchi & de Valois, 2000) —**longer presentation time ⇒ slower** (Katz et al., 1990; Treue et al., 1993) **⇒ lower contrast** (Kulikowski, 1972)	—**lower speed surround ⇒ nearer** (motion parallax-induced depth contrast, Graham & Rogers, 1982; Rogers & Graham, 1983)
(3) …greater luminance contrasts…	—**greater contrast ⇒ stronger geometrical illusions** (Wallace, 1975; Dworkin, 1997) —**color equiluminance ⇒ absence of geometrical illusions** (Livingstone & Hubel, 1987) —**greater contrast ⇒ larger** (Robinson, 1954; Weale, 1975; Georgeson, 1980; de Weert et al., 1998) —**greater contrast ⇒ lower spatial frequency** (Virsu, 1974; Virsu & Vuorinen, 1975; Kulikowski, 1975; Georgeson, 1980; Gelb & Wilson, 1983; Maddess & Kulikowski, 1999) —**greater contrast ⇒ greater repulsion** (Rentschler et al., 1975)	—**greater contrast ⇒ faster** (Hess, 1904; Thompson, 1982; Stone & Thompson, 1992; Kooi et al., 1992; Müller & Greenlee, 1994; Hawken et al., 1994; Ledgeway & Smith, 1995; Gegenfurtner & Hawken, 1996; Snowden et al., 1998; Blakemore & Snowden, 1999; Brooks, 2001) —**greater contrast moving surround ⇒ greater induced target speed** (Raymond & Darcangelo, 1990) —**greater contrast ⇒ less capture ⇒ greater relative speed** (Ramachandran, 1987; Ramachandran & Anstis, 1990; Murakami & Shimojo, 1993; Zhang et al., 1993)	—**luminance contrast contrast** (Ejima & Takahashi, 1985; Chubb et al., 1989; Cannon & Fullenkamp, 1991, 1993; Solomon et al., 1993; Snowden & Hammett, 1998)	—**color equiluminance ⇒ absence of depth** (Livingstone & Hubel, 1987) ? —**greater contrast surround ⇒ nearer** (*BELOW*)
(4) …greater distances…	—**greater stereo depth ⇒ larger** (Enright, 1989; Kaneko & Uchikawa, 1997; de Weert et al., 1998) —**lower accommodation ⇒ larger** (Biersdorf et al., 1963) —**lower convergence ⇒ larger** (Thouless, 1931; Heinemann et al., 1959; Biersdorf et al., 1963; Oyama & Iwawaki, 1972; Komoda & Ono, 1974)	—**farther ⇒ faster** (follows from 4A)	—**farther ⇒ lower contrast** (?)	—**depth contrast** (Werner, 1938; Harker, 1962; Pastore, 1964; Pastore & Terwilliger, 1966; Anstis et al., 1978; Brookes & Stevens, 1989; Pierce et al., 1998; van Ee et al., 1999; te Pas et al., 1997; Sato & Howard, 2001)
(5) …lower eccentricity …	—**nearer fovea ⇒ larger** (William James, 1890/1950; Helmholtz, 1867/1962; Newsome, 1972; Schneider et al., 1978; Georgeson, 1980; Davis, 1990) —**Hering illusion without the radial display** (Helmholtz, 1867/1962, see Liu & Schor, 1998). —**foveal attraction or repulsion?** (Mateeff & Gourevich, 1983; see Appendix for discussion)	—**nearer fovea ⇒ faster** (Campbell & Maffei, 1981; Tynan & Sekuler, 1982; Pantle, 1992; Schlykowa et al, 1993). —**nearer fovea ⇒ greater stereomotion speed** (Brooks & Mather, 2000) —**nearer fovea ⇒ less capture ⇒ greater relative speed** (De Valois & De Valois, 1991; Murakami & Shimojo, 1993; Zhang et al., 1993).	—**nearer fovea ⇒ lower contrast** (Georgeson, 1991)	—**nearer fovea ⇒ nearer** (barrel-distortion of large fronto-parallel planes, Helmholtz, 1867/1962)
(6) …lower projected distance from vanishing point of converging lines…	—**classical radial-display illusions such as Ponzo, Hering, Orbison** (Ehrenstein, 1925; Orbison, 1939; Berliner & Berliner, 1948; Leibowitz et al., 1969; Coren et al., 1976; Coren & Girgus, 1978; Schiffman & Thompson, 1978; Weale, 1978; Jordon & Randall, 1987; Changizi, 2001, 2003; Changizi & Widders, 2002) —**grid overlay** (see 6D)	—**nearer center of radial display ⇒ faster** (Swanston, 1984; Cesàro & Agostini, 1998)	—**nearer center of radial ⇒ lower contrast** (*BELOW*)	—**nearer center of radial display ⇒ nearer** (*BELOW*)
(7) …lower projected distance from focus of expansion…	—**nearer FOE ⇒ larger** (Anstis, 1989; Ramachandran & Anstis, 1990; Whitaker et al., 1999) —**flow repulsion, or capture** (Ramachandran, 1987; Anstis, 1989; Ramachandran & Anstis, 1990; De Valois & De Valois, 1991; Murakami & Shimojo, 1993; Zhang et al., 1993; Whitney & Cavanagh, 2000) —**forward induced motion ⇒ increased projected size** (Farnè, 1972, 1977; Reinhart-Rutland, 1983; Wade & Swanston, 1984; Whitaker et al., 1999) —**looming toward grid causes center to bow out** (Foster & Altschuler, 2001) —**dynamic Zanker-Hering analog** (Zanker et al., 2001)	—**nearer FOE ⇒ faster** (follows from 2B) —**looming illusions** (Widders color-balls, Changizi, 2003) —**looming toward grid causes center to flow out faster** (Foster & Altschuler, 2001)	—**nearer FOE ⇒ lower contrast** (?)	—**capture in depth** (Anstis, 1989; Edwards & Badcock, 2003) —**looming toward grid causes center to bulge** (Foster & Altschuler, 2001) Loom

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