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There and back again: Revisiting the on-time effect

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A R T I C L E I N F O

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A B S T R A C T

In apparent motion, static stimuli presented successively in shifted locations produce a subjective percept of continuous motion. Reducing stimulus exposure (or on-time) was shown to consistently increase the perceived velocity of apparent motion (Vision Research 29 (1989), 335–347), yet surprisingly little investigation has followed up on the discovery of this illusion. In five experiments, we delineate the boundary conditions of the on-time illusion in order to clarify its underlying mechanisms. Subjects viewed multi-item apparent-motion displays, in which at some point, on-time duration either increased or decreased. Objective velocity remained unchanged, yet participants had to judge whether they perceived the motion to become slower or faster. We observed the on-time illusion during both fast and slow apparent motion. The effect was not modulated by stimulus luminance, thus precluding an energy-summation account of the illusion. It generalized from speed perception to time perception in a temporal bisection task. The illusion was specific to apparent motion, as it did not occur with veridical motion. Finally, the illusion persisted when on-time and off-time were not confounded, that is, when off-time remained constant. These findings are discussed in the framework of current models of motion perception.

In December 2012, the movie "The Hobbit: An Unexpected Journey" (henceforth: "The Hobbit"; Jackson, 2012) premiered in cinemas worldwide. The movie was recorded using high frame rate (HFR) technology, which allowed for the recording of 48 frames per second (fps) instead of the standard 24 fps. Many cinemas played the movie in the HFR version, whereas others played it in the standard frame rate. Interestingly, when viewed in HFR, some people reported experiencing the movie as played in fast forward, at least for the first several minutes (e.g., Ryan, 2012). That is, even though the HFR did not change the objective velocity of motion in the movie, subjective velocity was distorted and perceived to be higher than in the standard version.

Such velocity distortions are a widely researched phenomenon in veridical motion. However, films do not actually contain veridical motion. Instead, perceived motion in films is based on "stroboscopic apparent motion" (henceforth, apparent motion), which refers to the perception of continuous motion from static stimuli presented successively in spatially shifted locations. Apparent motion in the laboratory has traditionally been investigated with simple two-item displays (but also sometimes with multi-item displays, see Sperling, 1976). With two-item displays, two light flashes are presented in rapid succession at two separate locations, producing the illusion that the same light moves from one location to the other. Motion vividness (i.e., likeness of apparent motion to veridical motion) depends on the interplay between the spatial and temporal distances used (e.g., Gepshtein & Kubovy, 2007; Kahneman, 1967). For instance, Kahneman (1967) showed that for a given spatial distance, the main factor that determines motion vividness with short-duration stimuli (approximately 100 ms or less) is the stimulus-onset asynchrony (SOA) between the two items, whereas for long-duration stimuli the main factor is the inter-stimulus interval (ISI).

Distortions in perceived velocity refer to any systematic difference between objective velocity and subjective perception of velocity. Although the motion percept in apparent motion is illusory, objective velocity in apparent motion has been defined as the distance between two object locations divided by the SOA (Koffka, 1935; Kolers, 1972). Thus, distortions of motion perception in apparent motion can be evaluated against this objective measure.

In one of the very few published papers investigating subjective perception of apparent motion velocity, Giaschi and Anstis (1989) reported a velocity illusion in apparent motion. These authors defined a cycle of apparent motion as the time between the onset of one stimulus and the onset the next stimulus along the motion path. They divided each cycle into the "on-time", during which the

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stimulus is physically present and the "off-time" during which the screen is blank. Their main finding was that the shorter the on-time was, the faster the stimulus appeared to move. For instance, with 100 ms cycles, apparent motion was perceived to be faster by approximately 16% with 50 ms on-time (and 50 ms off-time) than with 100 ms on-time (and null off-time). As apparent motion is ubiquitous in everyday life, the on-time effect can have important practical implications. For example, this effect might provide a straightforward explanation to the perceived speed-up in the HFR version of the Hobbit movie because each individual static frame was exposed for shorter durations (i.e., shorter on-time) than in the standard version.

Curiously enough, however, very little research (e.g., Castet, 1995) followed up on Giaschi and Anstis's research. In this study we sought to revisit the on-time effect. Specifically, our objective was to delineate the conditions in which the illusion is observed.

1. Experiment 1

In Experiment 1 we examined whether the on-time effect, which was previously observed with low velocities (Castet, 1995; Giaschi & Anstis, 1989) generalizes to higher velocities and whether it is modulated by this factor. Displays consisted of a dot presented at successive locations in a rightward direction, with objective apparent-motion velocities of either 4.16°/s (low velocity) or and 8.33°/s (high velocity). On each trial, a reference and a test apparent-motion events were presented one after the other as a single motion event. On-time and off-time were equal during the reference part of the motion event, and at some point (marking the beginning of the test part) on-time became either longer or shorter (see Fig. 1).

Participants were informed that each motion event contained a single velocity change and had to judge whether they perceived this change to be speeding or slowing of the motion. We used multi-item displays (as did Castet, 1995) and our on-time duration manipulation was similar to Giaschi and Anstis's (1989): the SOA between successive flickers was fixed and on-time and off-time durations varied inversely (see Fig. 1). Thus, objective velocity (i.e., the distance covered by the dot in a given amount of time) as well as the number of flickers remained constant throughout each motion event. In addition, in both velocity conditions (low and high) the distance covered by the dot was the same.

In this experiment, a replication of the on-time illusion with multi-item displays should manifest as a larger proportion of "faster" responses on shorter than on longer on-time trials. Of main interest was whether the illusion, if found, would be modulated by apparent-motion speed.

1.1. Method

The study received ethical clearance from the Ethics Committee for Human Experimentation of Tel Aviv University. Informed consent was obtained from each subject after explanation of the nature of the study.

1.1.1. Participants

The participants were 12 Tel-Aviv University undergraduate students who participated for course credit or for the equivalent of \$8.5 (mean age 25.9, SD = 2.95, 7 women). All reported normal or corrected-to-normal visual acuity.

1.1.2. Apparatus

Displays were presented in a dimly lit room on a 23″ LED screen, using 1920 × 1280 resolution graphics mode and 120 Hz refresh rate. Responses were collected via the computer keyboard. A chin-rest was used to set viewing distance at 50 cm from the monitor.

1.1.3. Stimuli

The fixation display was a gray 0.2° × 0.2° plus sign presented in center of the screen against a black background. The apparent-motion display consisted of two static bars and a dot, all white (110 cd/m^2). The two static vertical bars (1.7° of visual

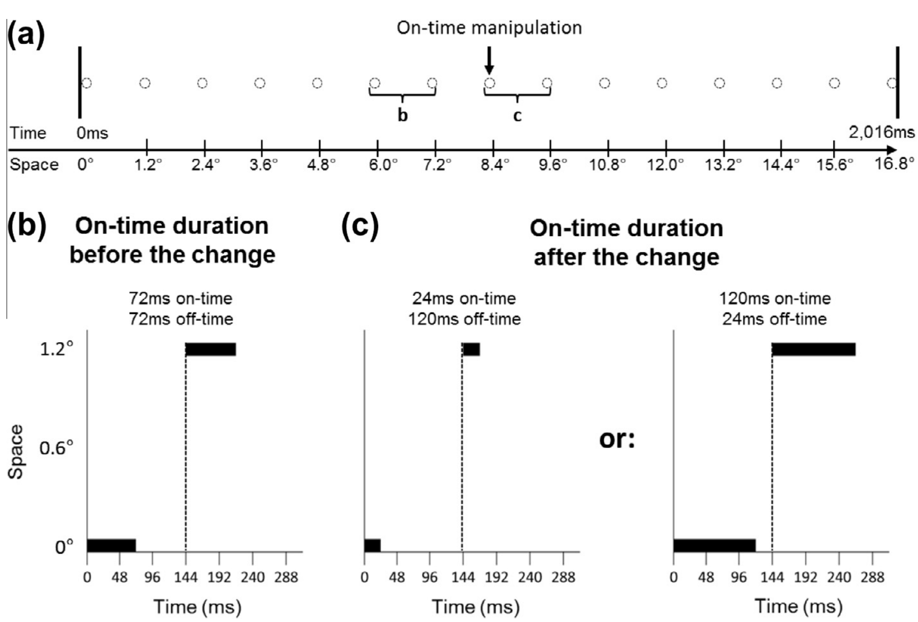

Fig. 1. Illustration of a trial with 4.16°/s velocity in Experiment 1; (a) a single dot appeared at fixed spatial intervals (outline circles represent the locations successively occupied by the dot) until the right-hand line marker was reached. Approximately at mid-screen on-time duration changed; (b) Space–time diagram of a single appearance of the reference motion (before the change), in which on-time duration was 72 ms; (c) Space–time diagram of a single appearance of the test motion (after the change), in which on-time duration was either 24 ms or 120 ms. The dashed vertical lines represent the SOA (144 ms).