Supplementary Figure 1. Expansion of the window of subjective simultaneity induced by the reduction in flash visibility and transient component. In each trial, only the test pair was presented, with a lag chosen from 13 values between −100 and +100 ms (the sign indicates the presentation order of the upper and lower flashes), and the observer made a yes-no judgment about whether the two flashes appeared to be simultaneous. The other experimental procedure was similar to that used for the interval judgments. We used four stimulus conditions of color flashes (presented without specific manipulation, with dynamic luminance flicker, followed by a saccade, or at low chromatic contrast), and two conditions of achromatic gratings (low and high spatial...
frequencies). a The proportion of simultaneity response as a function of the stimulus lag.

Chromatic stimuli. Observer: M.T. Using the maximum likelihood method, each response distribution was fitted by a Gaussian function,

\[ y = \min\{1, \ a \cdot \exp\left[-\frac{(x - m)^2}{2\sigma^2}\right]\}, \]

where \( a \) is the amplitude, \( m \) the mean, and \( \sigma \) the standard deviation of the Gaussian function. The \( \min \) function gives an upper bound of 1, even when \( a > 1 \). b As a measure of the range width of subjective simultaneity, the standard deviation of the Gaussian function is shown for each chromatic stimulus conditions. Symbols indicate individual data, and the bars indicate the average (n=3), with error bars showing ±1 standard error. c, d Results obtained with achromatic stimuli. In general, all of the stimulus manipulations that induced underestimation of the 100-ms interval gave rise to a widening of the range of subjective simultaneity.
**Supplementary Figure 2.** Magnitude of underestimation of flash intervals as a function of the SOA of the test pair. The vertical axis is the apparent duration obtained with DLF presentation, relative to that obtained under a control condition without DLF presentation. The results suggest that the interval underestimation decreases as the test SOA is increased and nearly disappears when the SOA reaches 500 ms.
Supplementary materials for

REDUCTION OF STIMULUS VISIBILITY COMPRESSES APPARENT TIME INTERVALS
by Masahiko Terao, Junji Watanabe, Akihiro Yagi and Shin'ya Nishida

Supplementary Methods

Observers
Observers were one of the authors (M.T.) and six volunteers who were unaware of the purpose of the experiments. All have normal or corrected-to-normal vision. Informed consent was obtained after the nature and possible consequences of the studies were explained.

Apparatus and Stimulus
The experiments were controlled by Matlab (Mathworks) with Psychophysics Toolbox extensions\textsuperscript{A1, A2} running on a Power Macintosh G4 (Apple). The visual stimulus was presented through a 10-bit graphic card (ATI Radeon 8500 AGP card), additionally with 14-bit BITS++ (Cambridge Research Systems) for achromatic gratings, on the screen of a 120-Hz monitor (SONY GDM-F520, or TOTOKU Calix) that subtended 42.7° in height and 57° in width at the viewing distance of 40 cm. The observer sat in a dimly illuminated room with his or her head fixed on a chin rest. A keyboard was placed in front of the observer to register responses. The movements of the dominant eye were monitored at 250 Hz with EyeLink II (SR research Ltd.).

Interval judgment with chromatic stimuli
Each trial started with the presentation of a uniform green field. After a 1.0-s delay, a fixation point was presented at the center of the screen (except for Condition 2, see below), and after a random delay (600-1100 ms), a pair of red flashes was presented. One flash appeared in the top 6° area of the screen, and the other in the bottom 6° area. They were thus spatially separated from each other by more than 30°. Each flash was presented for 1 monitor frame (nominally 8.3 ms). The temporal order of the two flashes was randomly determined, and the onset-to-onset flash interval was fixed at 100
ms. Two seconds later, a probe pair appeared. The probe flash order was randomly determined independent of the test flash order, and the inter-flash interval varied randomly between 8.3 and 200 ms. (When the test interval was increased to 500 ms, the probe interval was varied between 200 and 700 ms). The observer reported which interval appeared longer by pressing one of two keys. We instructed the observer to judge the interval between the two flash onsets (i.e., stimulus-onset asynchrony), not the interval between the first offset and the second onset. The CIE (1931) chromaticity coordinate of the green was x = 0.279, y = 0.605. The green intensity was subjectively equiluminant to the red flashes, adjusted for each observer by flicker photometry. The flash was pure red of the monitor (x = 0.622, y = 0.342), whose luminance was 11.4 cd/m². The flash intensity was 2.33 – 6.04 times of the detection threshold. For the low-contrast condition (Condition 5), the chromatic contrast of the flashes was two times the detection threshold of each observer. The detection threshold was measured for each test location using the constant method with yes-no judgments.

**Dynamic luminance flicker (DLF)**

The DLF was luminance fluctuation of the top and bottom areas where red flashes were presented. The luminance was randomly updated every monitor frame within the range of ± 25 % of the background intensity, with no correlation between the top and bottom areas. The DLF was presented from 1000-1500 ms (randomly determined) before the first flash till 1000 ms after the second flash.

**Saccade condition (Condition 2)**

On a uniform green field, a fixation point was presented at 15° left of the center of the screen. One second later, a saccade target was presented for 16.6 ms at 15° right of the center of the screen. The fixation point turned off 600-1100 ms (randomly determined) after the presentation of the saccade target. Then observer quickly made a saccade to the remembered target location. The presentation timing of the test flash pair was adjusted for each observer in such a way that the second flash was presented during a period from 100 to 10 ms before the saccade onset, and only the responses of the trials meeting this criterion were analyzed.
**Interval judgment with achromatic gratings (Conditions 6 & 7)**

For both test and probe stimuli, achromatic sinusoidal luminance gratings flashed, one at the top and the other at the bottom of a uniform gray field. The spatial frequency was 0.1 cycles per degree (cpd) for the low frequency stimulus, and 2.5 cpd for the high frequency stimulus. The mean luminance of the gratings and the background luminance were both 12.5 cd/m². The grating luminance contrast was 20 times the contrast threshold of each observer, measured using the constant method with the spatial 2AFC judgments.

**Supplementary Results**

To account for the present findings, we hypothesise that weak transient responses fail to trigger the detection of temporal asynchrony, which biases the overall interval judgments towards simultaneity. To obtain direct empirical support of this hypothesis, we examined how the window of subjective simultaneity was influenced by the reduction in flash visibility and transient component. The results (Supplementary Fig. 1) showed that all of the stimulus manipulation that induced underestimation of the interval (i.e., DLF, saccade, low contrast, and high SF) gave rise to a widening of the range of subjective simultaneity. If this is because the observers’ judgements simply became unstable, the peak simultaneity response should have been weakened, but it was rather strengthened. The results suggest that reductions of transient signals facilitate the perception of simultaneity, as we expected.

Some of our stimulus manipulations likely elongate the visual persistence of flashes. It is, however, unlikely that the change in visual persistence would have a strong influence on interval judgments. This is because the first and second flashes should be affected in a similar way, so the onset-onset interval of the two flashes, which our observers were instructed to judge, should remain unaffected. Our argument is further supported by an observation that the test flash interval was not underestimated when we mimicked the elongation of visual persistence by physically increasing the duration of test flashes: the point of subjective equality for the 100-ms test interval was 125.1±13.8 and 124.8±30.1 ms (average ± standard deviation of three observers) when the flash durations were 40 and 300 ms, respectively (measured with color flashes, no noise, original brief probe). Although the visual persistence may be relevant to the
current problem in that it is also related to the visual processing of temporal integration/segregation\textsuperscript{A6}, the visual persistency \textit{per se} is not a mechanism that produces apparent time compression.

Our hypothesis predicts that the underestimation of the interval will not be observed when the interval is too long for low-level offset sensors to encode, which would mean that another mechanism has to be used to encode elapsed time. In agreement with this prediction, as the test interval was increased, the effect of DLF on the apparent temporal underestimation was gradually reduced (Supplementary Fig. 2). When the interval reached 500 ms, the effect of DLF nearly disappeared. This suggests that there is a change of the time encoding mechanism between 100 and 500 ms. Another implication of this finding is that the effect we observed is unlikely to share the same underlying mechanism with the apparent temporal underestimations observed with 500-ms stimuli, including the one induced by adaptation to a high temporal frequency\textsuperscript{A7}.