Does time really slow down during a frightening event?

Chess Stetson
Matthew P Fiesta
David M Eagleman

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INTRODUCTION

Temporal judgments – such as duration, order, and simultaneity – are subject to distortions [1]. For example, perceived durations can be warped by saccades [2,3] or by an oddball in a sequence [4]. Temporal order judgments of actions and sensations can be illusory reversed by exposure to delayed motor consequences [5], and simultaneity judgments can be manipulated by repeated exposure to non-simultaneous stimuli [6]. Distortions in interval timing can be induced by narcotics such as cocaine and marijuana [7], as well as by disorders such as schizophrenia [8] and Parkinson’s disease [9].

However, an open question is whether subjective time is a unitary phenomenon, or instead whether it is underpinned by separate neural mechanisms that usually work in concert but can be dissociated under the right circumstances. In other words, when one temporal judgment changes, do the others necessarily follow suit?

To address this question, we turned to the common anecdotal report that time seems to have slowed down during a life-threatening event. We leveraged the fact that the visual brain integrates over a small window of integration (usually ~80 msec), they are perceived as a single stimulus [10]. As an illustration of this principle, a child’s toy known as a thaumatrope has, for example, a picture of a bird on one side of a disc and a picture of a tree branch on the other; when the disc is wound up and spun quickly so that both sides are seen in rapid alternation, the bird appears to be resting on the branch. Because the stimuli are alternating so rapidly that the visual system cannot distinguish them temporally; they are seen as though simultaneously present.

We applied this characteristic of the visual system to the perception of rapidly alternating digits. When shown a digit and its negative image at a slow rate of alternation (Fig. 1a), participants have no trouble identifying it. As the rate of alternation increases, a sharp threshold is reached after which the information is presented too rapidly and the digit can no longer be discriminated from a uniform display (Fig. 1b) – that is, at a high rate of alternation the images perceptually overlap as though they were presented simultaneously.

To test whether humans experience increased temporal resolution during frightening events, we designed an experiment in which participants could accurately detect a visual stimulus only if they were experiencing supra-normal temporal resolution.

METHODS

We leveraged the fact that the visual brain integrates over a small window of time. If two or more stimuli arrive within a single window of integration (usually ~80 msec), they are perceived as a single stimulus [10]. As an illustration of this principle, a child’s toy known as a thaumatrope has, for example, a picture of a bird on one side of a disc and a picture of a tree branch on the other; when the disc is wound up and spun quickly so that both sides are seen in simultaneous presentation.
To establish temporal thresholds, each participant was asked to report the numbers shown on the device, starting with a slow repetition frequency. Upon correct digit identification, we randomized the digit to increase the alternation frequency by decreasing the period 6 ms. The threshold was identified as the frequency at which a participant was unable to correctly identify randomized numbers after 3 consecutive presentations. We tested 13 participants during the daytime and 7 at nighttime and found average threshold periods of 47.4±13 ms and 33.4±9 ms, respectively.

After obtaining thresholds, we harnessed participants safely to a platform which was then winched 46 m off the ground to the apex of a Suspended Catch Air Device (SCAD) tower (Fig. 1d). The chronometer was strapped to the participant’s forearm like a wristwatch, and was programmed to display a random number alternating at a period 6 ms faster than their determined threshold. Participants were released from the top of the tower and experienced free fall for 2.49 s before landing safely in a net. During the fall, they attempted to read the digits for subsequent report. If higher temporal resolution were experienced during the freefall, the alternation rate was increased the digits and increased the alternation frequency by decreasing the period 6 ms. The threshold was identified as the frequency at which a participant was unable to correctly identify randomized numbers after 3 consecutive presentations. We tested 13 participants during the daytime and 7 at nighttime and found average threshold periods of 47.4±13 ms and 33.4±9 ms, respectively.

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One of the two experimenters remained on the platform to monitor for eye closure. One participant who closed her eyes for the entire free fall was excluded from the study; all others kept their eyes open during at least part of the freefall.

Upon landing in the net, participants verbally reported the displayed number; if they were unsure, they were asked to deliver their best guess. The displayed number was verified by the experimenters by slowing the display to an easily readable alternation rate, and answers were scored for accuracy (correct reporting of both digits = 100%, one digit = 50%, neither = 0%).

Additionally, 7 participants made duration judgments. After watching another participant take the freefall, but before they took the freefall themselves, we asked these participants to imagine being released from the top and then falling through the air until they hit the net. At the moment when they pictured their release from the top, they were to press the start button on a stopwatch; at the time that they imagined hitting the net, they were to press the stop button. We repeated the same measurement just after they experienced the free fall themselves, this time asking them to remember being released from the top and estimate how long it took until they hit the net.

To avoid incentivization, participants were not compensated except for the cost of the SCAD dive. All participants gave written informed consent as approved by the IRB at the University of Texas, Houston Medical School.

Figure 1. Measuring temporal resolution during a fearful event. (a) When a digit is alternated slowly with its negative image, it is easy to identify. (b) As the rate of alternation speeds, the patterns fuse into a uniform field, indistinguishable from any other digit and its negative. (c) The perceptual chronometer is engineered to display digits defined by a uniform field, indistinguishable from any other digit and its negative. (d) The Suspended Catch Air Device (SCAD) diving tower at the Zero Gravity amusement park in Dallas, Texas (www.gojump.com). Participants are released from the apex of the tower and fall backward for 31 m before landing safely in a net below.

Figure 2. No evidence for fear-induced increase in temporal resolution. (a) Participants’ estimates of the duration of the free-fall were expanded by 36%. The actual duration of the fall was 2.49 sec. (b) If a duration expansion of 36% caused a corresponding increase in temporal resolution, a 79% accuracy in digit identification during the fall would be predicted (left bar, see text). However, participants’ accuracy in-flight was significantly less than expected based on this theory (middle bar, p=2×10^-4). In-flight performance was no better than ground-based controls (right bar, p=0.86), in which the experimental sequence was identical except that the participants did not perform the free fall. The performance scores are averaged over participants, each of whom performed the experiment only once and had a potential performance of 100% (correctly reported both digits), 50%, or 0%. Note that participants did show better-than-chance performance on both the in-flight experiment and ground-based control (chance = 10% accuracy) even though the alternation period had been set to 6 ms below their threshold. This performance gain might be attributable to perceptual learning; it may also be because movement of the chronometer makes it slightly easier to read due to separation of successive frames, and participants sometimes moved the device involuntarily as they hit the net. To ensure parity between the comparisons, we applied a small jerk to control participants’ wrists to mimic how the device moved when free-fall participants hit the net. Asterisks represent p<0.05.

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RESULTS

Using the retrospective stopwatch estimation, participants’ duration estimates increased by an average of 36% when they recalled their own fall (from 2.17 ± 0.24 s to 2.96 ± 0.31 s, p < 0.05, paired t-test, one-tailed, Fig. 2a), consistent with their verbal report that their fall had “seemed to take a very long time”.

But was there a concomitant increase in temporal resolution? For a flickering display such as the one in this experiment, participants typically exhibit a sharp threshold between frame rates at which they can perceive the stimulus, and frame rates at which they cannot (around 3 ms, determined in a separate experiment). Therefore, we would expect that when measuring near their baseline threshold, a small increase in a participants’ temporal resolution would translate into a large increase in perceptual performance. By fitting a psychometric curve to participants’ pre-jump data, and then shifting it by the amount predicted by a 36% speed-up of their temporal resolution, we obtained an estimate of the perceptual performance we might expect during the free fall. The mean expected performance (measured as correct digit identification) is plotted in Figure 2b, along with the actual performance. In a control experiment, we repeated the experimental procedure, but participants remained on the ground. The mean in-flight performance was much less than what we predicted, and no different from the ground-based control (p = 0.98). Thus, while duration estimates increase during a high-fear situation (Fig. 2a), the lack of a matching increase in perceptual performance (Fig. 2b) indicates that duration estimates are not directly linked to temporal resolution.

DISCUSSION

We have tested whether the subjective duration increase of a frightening event is due to increased temporal resolution (as from the speeding of a camera) or instead whether duration distortions do not necessarily entail the expected consequences of a unitary time slowing down. Understanding how and why duration estimations change constrains neural models of time representa-

REFERENCES

1. Eagleman DM, Tse PU, Buonomano D, Jansen P, Nobre AC, et al. (2005) Time and the brain: how subjective time relates to neural time. J Neurosci 25: 10369–10371.
2. Yarrow K, Haggard P, Heal R, Brown P, Rodwell JC (2001) Illusory perceptions of space and time preserve cross-saccadic perceptual continuity. Nature 414: 302–305.
3. Morrone MC, Ross J, Burr D (2005) Saccadic eye movements cause compression of time as well as space. Nat Neurosci 8: 950–954.
4. Tse PU, Inouigator J, Rivest J, Cavanagh P (2004) Attention and the subjective expansion of time. Perception & psychophysics 66: 1171–1189.
5. Sterton C, Cui X, Montague PR, Eagleman DM (2006) Motor-sensory recalibration leads to an illusory reversal of action and sensation. Neuron 51: 631–639.
6. Fujisaki W, Shimojo S, Kashino M, Nishida S (2004) Recalibration of auditoryvisuall simultaneity. Nat Neurosci 7: 773–778.
7. Buhusi CV, Meck VH (2005) What makes us tick? Functional and neural mechanisms of interval timing. Nature reviews 6: 755–765.
8. Davalos DB, Kaley MA, Ross RG (2003) Effects of interval duration on temporal processing in schizophrenia. Brain Cogn 52: 295–301.
9. Riesen JM, Schneider A (2001) Time estimation in Parkinson’s disease: normal long duration estimation despite impaired short duration discrimination. J Neurol Neurosurg Psychiatry 248: 27–33.
10. Di Lollo V (1977) Temporal Characteristics of Iconic Memory. Nature 267.
11. Matell MS, King GR, Meck WH (2004) Differential modulation of clock speed by the administration of intermittent versus continuous cocaine. Behavioral neuroscience 118: 150–156.
12. Yamazaki T, Tanaka S (2005) Neural modeling of an internal clock. Neural computation 17: 1032–1058.
13. Parvathine V, Eagleman DM (2007) The effect of predictability on subjective duration. Under review.
14. Frisman LJ, Freeman AW, Troy JR, Schweitzer-Tong DE, Etoh-Cugell C (1987) Spatiotemporal frequency responses of cat retinal ganglion cells. The Journal of general physiology 89: 103–112.
15. Keysers C, Xiao DK, Foltak P, Perrett DI (2001) The speed of sight. Journal of cognitive neuroscience 13: 90–101.
16. Curran S, Watis J (2000) Critical flicker fusion threshold: a potentially useful measure for the early detection of Alzheimer’s disease. Hum Psychopharmacol 15: 103–112.
17. Farnsworth MS, Gale GD (2003) The amygdala, fear, and memory. Annals of the New York Academy of Sciences 985: 125–134.
18. Hamann SB, Ely TD, Grafton ST, Kitis CD (1999) Amygdala activity related to enhanced memory for pleasant and aversive stimuli. Nat Neurosci 2: 289–293.
19. Cahill L, Babinsky R, Markowitch HJ, Gaughrn JL (1995) The amygdala and emotional memory. Nature 377: 295–296.
20. Olsson A, Phelps EA (2007) Social learning of fear. Nat Neurosci 10: 1105–1110.

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Author Contributions

Conceived and designed the experiments: DE CS. Performed the experiments: DE CS. Analyzed the data: DE CS. Contributed reagents/materials/analysis tools: CS MF. Wrote the paper: DE CS.