Distortion Effects of Sky Background in Video Games on Perceived Duration

Qin He
Polytechnic Institute, Purdue University
West Lafayette, Indiana
he435@purdue.edu

Xingyu Lei
Polytechnic Institute, Purdue University
West Lafayette, Indiana
lei64@purdue.edu

Junzhe Shen
Polytechnic Institute, Purdue University
West Lafayette, Indiana
shen433@purdue.edu

ABSTRACT

After years of development, video games nowadays can provide the players more immersive experience with mature techniques and attract more attention in the past decade. In many researches on video games, a phenomenon called time distortion is reported where players lose their sense of time passing, and put more time than they thought in gaming. This distortion on perceived duration, as important descriptor of gaming experience and potential reason for gaming addiction, has been studied by many researchers. It is widely accepted that in most cases perceived duration will be shortened in gaming. Highly concentrated attention on the game and neglect of temporal information are believed to be the main reason for the time distortion and game addiction. But the prior hypothesis of addiction results in the neglect of the complexity of the virtual environments in modern games and other possible reasons of time distortion. We believe that more factors causing time distortion can be found in video games and can be applied in more fields than researches on gaming addiction. Therefore, we explore one common factor of the virtual environment, the sky background in video games, and find more possible reasons for time distortions in gaming. In this paper, we describe the experiment we designed for this exploration and the main findings obtained in the experiment. Discussions about the experimental results and the findings are also given to have an objective description of our exploration.

KEYWORDS

perceived duration, time distortion, video games, virtual environment

1 INTRODUCTION

Due to its rapidly development and its popularity among a variety of crowds, video games have attracted attention of researchers from different areas in the past several decades. After years of development, video games can bring a more immersive experience these days. The popularity and portability of smart phones strengthen the importance of mobile games and change the purpose and ideas of game design. Games that researchers focusing on also keep changing from early arcade games, online games to mobile games these days[1, 16], as the technology for graphics and gaming devices develop. Experience and addiction are always among the core research topics. It is believed that video games nowadays have stronger abilities and tendencies to encourage continuous use [7, 12], which increase the concern that video games can be potentially addictive activities [10]. 'Addictive' game players are generally observed to have the experience of 'time distortion'[7, 12, 19, 20]: players report that they lose their sense of time passing. Therefore, time perception, or more accurately, duration perception in gaming, as an important criterion on video game addiction, also a potential reason for addiction [19] and a good descriptor of gaming experience [11, 20], should be further explored.

Time perception is an unreliable sense that can be easily affect by multiple internal and external factors. The time perception-affecting factors are widely studied by psychologist. When it comes to video games, time distortion is considered to be mainly caused by an experience called 'flow' in most cases[6]. More factors like music have been explored as the reason that create immersive experience and time distortion in gaming [20]. However, with the development of computer graphics and virtual environment, the virtual experience in gaming is much closer to real world experience than before, which makes the time perception-distorting factors as complex as the ones in real world. Thus it also can be difficult to give a general conclusion of what may cause time distortion in gaming. We explore the sky scene in the background and try to discuss its potential of causing time distortion in gaming. It is just one single aspect in the virtual environment, but frequently used in most video games and may contains multiple time perception-distorting factors in it, such as repeated stimuli and circadian rhythm. Therefore the exploration of it can be meaningful to improving gaming experience and avoiding game addiction.

In this paper, we describe the simple experiment we design and used for exploring the time distortion caused by different sky scene. Results of the experiments, analysis and discussion are also given to explain our findings. This paper is organized as follows. Section 2 describes several basic concepts about time distortion in gaming. Section 3 describes the experiments used for collecting the perceive durations under different sky scene. Section 4 gives the results and some basic analysis. Section 5 gives the discussion about our experiments and findings.

2 TIME DISTORTION

Researches show that time perception is an unreliable sense [4, 17, 18]. It is still unclear how the perception is formed, but it is known to be easily affect by multiple internal and external factors. Due to its variability, a psychological concept called time distortion is introduced to describe the phenomenon that the subjective time perception affected by different factors. As one of the most field of study within psychology and psychology and neuroscience, has extremely complex mechanism. It is believed to be a result of multiple inner factors like neurotransmitter [21] and heart rates [2], as well as external factors like time of the day [15] and space location [13]. It also consists of multiple sub concepts including circadian rhythm,

simultaneity, temporal order and duration. According to the goal of exploring its effects in gaming, we focus on the concept of duration.

2.1 Perceived Duration

Perceived duration indicates the judgment on a time interval between two successive events, sometimes can be further divided into prospective and retrospective duration, according to the time when judgment is made [23]. Which exact part of the nerves system, or which cells performs this basic judgment is still under study. For now it is generally believed that cerebral cortex, basal ganglia and cerebellum work on this perception together [18]. However, the factors that can affect the judgment are well explored. For example, R. Block, etc. [4] prove the relationship between human aging and duration judgment. S. Droit-Volet, etc.[8] explore the effect of emotion on perceived duration, while C. Stetson, etc. [22] more specifically explore the impact of fear. Other factors like time of the day [15], repeated stimuli [17], etc. have also been proved to have significant impact on perceived duration. The factors acting on perceived duration are as complex as the factors acting on time perception itself.

2.2 Flow and Time Distortion

Perceived duration, rather than other sub concept of time perception, is more closely related to the description of gaming experience and addiction because the degrees of addiction and immersion are always described by the distortion in the sense of time passing [16]. Generally, time distortion is further divided into three classes, time dilation, time compression and time reversal, which are used to describe some much more serious effects usually caused by psychoactive substance [14]. R. Patrick, etc. [19] firstly introduce this concept to describe the degree of 'disorder' in online game addiction.

As stated above, time distortion can be caused by many factors including psychoactive drugs. But when it comes to video games, time distortion is believed to be mainly caused by an experience called 'flow'. Flow is recognized and named by M. Csikszentmihalyi and I. Csikszentmihalyi [6], stated as a mental state of operation in which a person performing an activity is fully immersed in a feeling of energized focus, full involvement and enjoyment in the process of the activity [5]. Applied with the experimental results on perceived duration-affecting factors, researchers believe that time distortion in gaming experience should be caused by the competition between temporal and non-temporal information processing, or the factor of attention [19], and positive emotions like enjoyment [8]. And it is repeatedly proved by the experiments by T. Sanders and P. Cairns [20], R. Patrick, etc. [19], Y. Lin, etc. [16] and so on.

2.3 Time perception in gaming

There are few researches directly aims at the time perception-affecting factors in gaming, which can be expected because most stimuli and environment settings under experimental control can be involved in virtual environments. That means the environment in video games can be as complex as the real world, thus it can be extremely difficult as well, to give a general conclusion of what may cause time distortion in gaming.

Figure 1: Game interface used for the experiment.

As stated above time distortion in gaming is generally believed to be mainly caused by an experience called highly focused attention and positive emotions. While it seems to be a solid conclusion, the priori hypothesis of addiction and time compression also result in the neglect of other possible reasons. However, we believe that the virtual environments in games can also affect the time perception through at least two aspects other than flow experience, both of which are proved to have impacts on perceived duration, but haven't be tested in video games yet: repeated stimuli and circadian fluctuation. Repeated stimuli is proved to have obvious impact on perceived duration by W. Matthews [17]. It can be produced and frequently used in video games in the form of periodic motion of objects and reuse of source files. Change of days and nights, or time of the day, couldn't be reproduced in early video games but plays important roles in modern ones. It is proved to has impact on time perception [15] and believed to be a result of circadian rhythm. We think some factors like brightness and frequency of ambient light, as stimuli themselves, can be potential reasons that lead to the circadian fluctuation of perceived duration. These are all basic elements in computer graphics and can be easily generated in video games and are the guide of our experiment design.

3 METHODOLOGY

In order to explore how different virtual environments would distort the players' perception of duration, we focus on one most common scene of virtual environment – the sky. We designed a game that runs with different sets of virtual sky and ask subjects to play the game while counting time. Quantitative measurements of game duration are recorded for each subject with each sky settings. The time distortion caused by sky background in gaming can be demonstrated by comparing the difference between perceived durations of each subject under different sky settings.

The experiment is carried out using a 2D platform game that we developed on Unity. The game is designed as simple as possible to ensure that subjects are able to count while playing but aren't focusing on counting, that is, the temporal information, to simulate general gaming situation where highly focused attention is paid on non-temporal information. The game has a character that is automatically moving forward with uniform speed, and random generated obstacles approaching the character. To avoid getting hit,

players need to control the character to jump over these obstacles. The game has multiple rounds. In each round, different sky background is displayed. Players start counting time when the game starts. Then end the game when they think a certain duration of time has passed. The actual durations of each round are recorded as the results of the experiment. The game interface is shown in Figure. 1

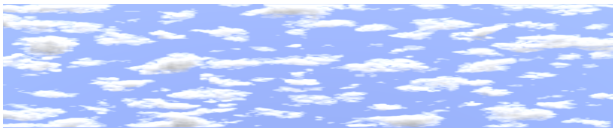
The test for each subject consists of 7 rounds, with 7 different settings for the sky backgrounds, related to three aspects of a sky scene: the moving speed of cloud, the coverage of cloud, and the lighting situation of different times of a day. 5 sky background images are generated using Houdini to present different coverage of cloud and different light situation. All the background images share a similar cloud pattern as shown in Figure 2, to avoid players being affected by the patterns. The speed of cloud are simulated by setting different scrolling speed for the sky background images.

The background image with moderate coverage of cloud is used in round 1, 2 and 3, which presents a partly cloudy sky in the daytime. In round 1 the image rolls with moderate speed, and the results in this round are set as the benchmark for comparison and analyses. In round 2 and 3 the same image is used but rolls with lower and higher speed separately to present different speed of cloud. In round 4–7, different background images are used with the same scrolling speed as round 1 as the control variable. Images with higher and lower coverage of cloud are used in round 4 and 5 to present cloudy and clear sky in the daytime separately. Images with moderate coverage of sky at sunset and at night are used in round 6 and 7. All the 7 adopted settings are shown in Table 1, with variable of interest marked with shading.

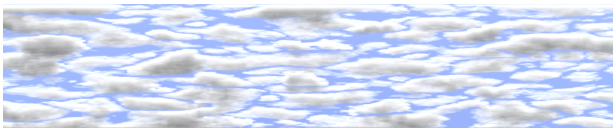
The target duration for subject to count is 15 seconds, which should be long enough for players to pay full attention to the simple game, but not too long for them to perform duration perception. By pressing 'P' on the keyboard, the subject starts a round of game and also starts the background timing. Space bar is used to control the character jumping over the obstacles. Key 'p' is pressed again to end the round and the timing, when the subject thinks 15 seconds has passed. Then the actual duration is recorded for this round. After each round, the setting of sky background is changed and the subject repeats the steps above until all 7 rounds complete. There is no punishment for the character being hit by the obstacles, to keep moderate pressure. Because our goal is to explore the distortion effects of the virtual environment rather than pressure or attention. The actual durations being recorded are shown only after all 7 rounds complete, then be used as the results for analyses.

Table 1: Different experimental settings of the sky. Variable of interest in each group is marked with shading.

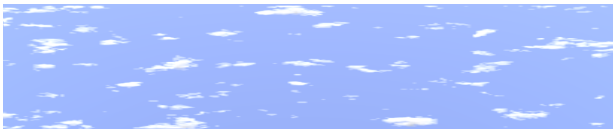
Group number	Cloud Movement Speed	Cloud Intensity	Brightness
Sky1(Benchmark)	Moderate	Normal	Daytime
Sky2	Fast	Normal	Daytime
Sky3	Slow	Normal	Daytime
Sky4	Moderate	Low	Daytime
Sky5	Moderate	High	Daytime
Sky6	Moderate	Normal	Sunset
Sky7	Moderate	Normal	nighttime



(a) Background image used for round 1, 2 and 3



(b) Background image used for round 4



(c) Background image used for round 5

(d) Background image used for round 6

(e) Background image used for round 7

Figure 2: Sky background images of different settings.

4 RESULTS AND ANALYSES

Our experiment involved 38 subjects in total, each of which took all 7 rounds of the game with different experimental settings. Most of them are graduate students, including 15 females and 23 males. After removing one result where the subjects failed in one test, 37 sets of valid data (14 females and 23 males) are given in table 2. Results under experimental setting of moderate cloud speed and partly cloudy sky are set as the benchmark for the compare of statistical results, as stated in Section 3. Because it is the most common sky scene in most video games and the results under this setting are accurate to the target duration. Statistical analyses are also used on results of each subjects in order to find potential features to identify the vulnerability of subject to the perceived duration-distorting factors. It is necessary to state that all the results are obtained under gaming environment stated in Section 3. Therefore all the results and analysis can be only used for discussion in time perception in gaming rather than general real life.

Table 2: Experimental results (in second, to the nearest thousandth) of perceived duration of each subject under different experimental settings. The target duration is 15 seconds.

Subject Number	moderate speed partly cloudy sky	low speed partly cloudy sky	high speed partly cloudy sky	moderate speed cloudy sky	moderate speed clear sky	moderate speed sunset	moderate speed night
subject #1	14.446	14.943	14.464	14.695	13.950	15.026	15.027
subject #2	18.756	20.363	20.084	19.768	19.274	19.550	21.197
subject #3	11.962	12.756	13.037	14.065	13.337	12.375	12.772
subject #4	12.657	12.957	13.670	15.242	14.487	13.518	14.877
subject #5	17.696	19.666	17.985	21.662	20.315	17.606	16.070
subject #6	14.479	17.661	16.765	17.859	16.169	19.418	18.820
subject #7	12.988	13.854	14.669	14.212	14.674	14.876	13.785
subject #8	14.155	14.833	10.626	11.493	13.032	12.387	12.372
subject #9	12.700	13.343	13.307	12.921	13.067	12.181	12.526
subject #10	19.613	13.970	13.971	14.299	14.240	15.436	18.565
subject #11	14.065	15.277	15.647	15.830	14.326	15.440	15.633
subject #12	14.884	21.540	28.128	21.059	24.237	20.791	20.467
subject #13	14.178	15.719	16.036	18.924	16.536	16.627	16.845
subject #14	11.132	12.293	11.894	11.364	12.179	12.143	11.648
subject #15	13.276	15.734	15.733	16.248	17.684	17.735	22.204
subject #16	9.475	9.907	11.265	11.927	13.203	13.219	14.032
subject #17	14.712	15.209	14.247	15.590	16.109	16.468	16.047
subject #18	20.046	29.226	28.608	26.168	24.435	24.833	23.789
subject #19	14.181	18.042	13.923	15.474	13.883	15.324	15.606
subject #20	11.683	11.141	10.995	11.518	10.639	11.545	11.711
subject #21	9.395	8.896	13.038	9.443	8.964	11.232	8.996
subject #22	15.730	16.617	15.414	17.829	18.118	16.383	16.659
subject #23	19.818	28.156	29.402	24.990	26.982	24.693	25.724
subject #24	10.024	10.381	9.361	12.133	11.177	12.825	11.963
subject #25	20.975	19.666	21.520	24.636	21.106	23.144	22.083
subject #26	15.924	30.527	26.145	24.479	26.860	29.216	25.047
subject #27	14.052	14.613	14.514	15.540	14.613	15.076	15.392
subject #28	13.900	13.834	15.125	14.929	15.847	15.241	15.939
subject #29	14.793	16.071	16.650	14.662	14.993	15.291	16.270
subject #30	17.892	19.565	23.327	24.270	26.343	24.915	25.115
subject #31	13.585	17.015	16.799	18.108	20.279	17.908	19.531
subject #32	15.104	16.319	17.145	16.994	16.318	20.607	19.927
subject #33	15.207	17.783	18.025	17.544	19.482	19.019	18.821
subject #34	14.497	14.728	15.291	16.782	17.511	17.146	17.479
subject #35	14.701	15.851	16.593	16.360	16.055	15.775	17.442
subject #36	18.562	22.104	23.221	23.566	23.160	22.450	22.753
subject #37	15.943	17.616	16.906	14.759	15.727	14.813	13.814

4.1 Distortion Effects Caused by Different Changes

We examine some basic statistics of experimental results with every experimental settings to explore the duration effects of possible external factors. Mean, standard deviation and quartiles are used for this basic statistical analysis. Surprisingly we found that all kinds of changes in the sky background can result in time compression, that is, shorter perceived duration. With the same target perceived duration of 15 seconds, the average of actual time passes in all the other 6 rounds exceed the average time in the benchmark round for 1.92 – 2.43 seconds. More specifically, changes in weather and circadian rhythm, or time of the day may result in more significant time compression, while effects of speed changing presents higher level of fluctuation from subject to subject, shown in larger standard deviations. Results of statistical analyses are shown in table 3.

Possible explanations may lie in the ways through which these experimental settings affect time perception. Changes in the visual appearance of the scene, such as brightness or color, may distract the players and cause more competition between temporal and non-temporal information [19]. And this distraction should be universal among human beings since we share the similar visual system. But the speed of cloud is supposed to affect time perception as repeated stimuli [17]. Its effect may depend on the neural response to a stimulus [9]. We believe the correlation with neural response can be the reason for the larger difference among subjects.

4.2 Distortion Effects between Different Individuals

We also examine the experimental results of each subjects to explore the duration effects of possible internal factors. Mean and standard deviation are calculated using results from all 7 rounds of tests for each subject. Then the distances of the means of the results to the target duration 15 seconds are used to present the accuracy, and the standard deviations are used to present the precision of their perceived duration, separately.

Table 3: Statistical analyses of each rounds with different settings of the sky.

statistic analysis	moderate speed partly cloudy sky	low speed partly cloudy sky	high speed partly cloudy sky	moderate speed cloudy sky	moderate speed clear sky	moderate speed sunset	moderate speed night
mean	14.7887	16.7075	16.8522	16.9551	17.0083	17.0875	17.2149
standard deviation	2.83104	4.82155	4.97032	4.29191	4.54449	4.26929	4.17280
1st quartile	13.1319	13.8439	13.7965	14.2553	13.9165	14.1655	13.9232
2nd quartile (median)	14.4788	15.7335	15.6467	15.8304	16.0550	15.7748	16.2695
3rd quartile	15.9331	18.8037	18.0048	19.3462	19.8809	19.4842	20.1973

As expected, high correlation between the distances and the standard deviations is shown with a Pearson's linear correlation coefficient (PLCC) of 0.7158. That is, the less accurate one can perceive the duration, the more vulnerable he or she is to the perceived duration-affecting factors. This simple conclusion can be a result of multiple psychological and physical reasons such as emotion [8] and heart rates [2]. But it may not be solid enough considering the sample size of this experiment is relatively small.

5 DISCUSSION

Most of our findings are consistent with previous works in this field, the results obtained in our experiment support the conclusion that most factors in gaming can shorten the perceived duration. But there are also some of our results that may challenge the previous works. Comparing the results from the test with sky background of different time, we can see that in our experiment, scene of sunset and night can shorten the perceived duration, rather than lengthen them as presented by K. Kuriyama, etc. [15]. We speculate that the actual time when the experiment is taken leads to this different results. It is well known that visual system is not the only basis of circadian rhythm [3]. Therefore the effects of the day and night cycle in video games on perceive duration may be different from the cycle in real life. We also find the average results of the first round unexpectedly accurate, and even slightly shorter than the target duration (14.7887s). It challenges the opinions of most previous works that perceived duration will be shorten in gaming because players pay more attention to the game contents rather than the time passing [7, 11, 12, 16]. Actually video game contents always contains temporal information as a part of game mechanics and competition. Therefore, the assumption of competition between temporal and non-temporal information resulting time compression in gaming sometimes may fail to explain the distortion in perceived duration. Researchers may have jumped to this conclusion because of the priori hypothesis of addiction.

There are also some possible flaws in present experiment, including relatively small sample size with valid results from only 37 subjects, the setting of one single target duration of 15 seconds. One of the possible flaws is that every subject play the 7 rounds of game in the same order. This may undermine our study with a potential correlation between the data and the order of tests. These potential correlation can be speculated from the statistical results of every rounds, where the average perceived duration increases as the round number increases. On the other hand, the game contents are always the same. The whole experiment can be seen as a process of repeated work. Therefore potential correlation between time distortion and repeated work may be a possible topic for future works, which may be necessary to claim more findings in the distortion effects on perceived duration in gaming.

REFERENCES

[1] Suliman S. Aljomaa, Mohammad F. Al.Qudah, Ismael S. Albursan, Salaheldin F. Bakhiet, and Adel S. Abduljabbar. 2016. Smartphone addiction among university students in the light of some variables. *Computers in Human Behavior* 61 (2016), 155 – 164. https://doi.org/10.1016/j.chb.2016.03.041

[2] Alessandro Angrilli, Paolo Cherubini, Antonella Pavese, and Sara Manfredini. 1997. The influence of affective factors on time perception. *Perception & psychophysics* 59, 6 (1997), 972–982. https://doi.org/10.3758/BF03205512

[3] Jürgen Aschoff. 1965. Circadian rhythms in man. *Science* 148, 3676 (1965), 1427–1432.

[4] Richard A Block, Dan Zakay, and Peter A Hancock. 1998. Human aging and duration judgments: A meta-analytic review. *Psychology and Aging* 13, 4 (1998), 584. https://doi.org/10.1037/0882-7974.13.4.584

[5] Chadchumley, Henry chianski, Narky Blert, Salvidrim!, Faot, ClueBot NG, and CiaranMalik. 2018. Flow (psychology). https://en.wikipedia.org/wiki/Flow_(psychology). Accessed October 31, 2018.

[6] Mihaly Csikszentmihalyi and Isabella Csikszentmihalyi. 1975. *Beyond boredom and anxiety*. Vol. 721. Jossey-Bass San Francisco.

[7] Brian D Ng and Peter Hastings. 2005. Addiction to the Internet and Online Gaming. *Cyberpsychology & behavior : the impact of the Internet, multimedia and virtual reality on behavior and society* 8 (05 2005), 110–113. https://doi.org/10.1089/cpb.2005.8.110

[8] Sylvie Droit-Volet, Sophie L Fayolle, and Sandrine Gil. 2011. Emotion and time perception: effects of film-induced mood. *Frontiers in integrative neuroscience* 5 (2011), 33. https://doi.org/10.3389/fnint.2011.00033

[9] David M. Eagleman and Vani Pariyadath. 2009. Is Subjective Duration a Signature of Coding Efficiency? *Philosophical transactions of the Royal Society of London. Series B, Biological sciences* 364 (08 2009), 1841–51. https://doi.org/10.1098/rstb.2009.0026

[10] Mark Griffiths and Richard TA Wood. 2000. Risk factors in adolescence: The case of gambling, videogame playing, and the Internet. *Journal of gambling studies* 16, 2-3 (2000), 199–225.

[11] Yavuz Inal and Kursat Cagiltay. 2007. Flow experiences of children in an interactive social game environment. *British Journal of Educational Technology* 38, 3 (2007), 455–464. https://doi.org/10.1111/j.1467-8535.2007.00709.x

[12] Naomi J. Thomas and Frances Martin. 2010. Video-arcade game, computer game and Internet activities of Australian students: Participation habits and prevalence of addiction. *Australian Journal of Psychology - AUST J PSYCHOL* 62 (07 2010), 59–66. https://doi.org/10.1080/00049530902748283

[13] Eli J Jaldow, David A Oakley, and Graham CL Davey. 1989. Performance of decorticated rats on fixed interval and fixed time schedules. *European Journal of Neuroscience* 1, 5 (1989), 461–470. https://doi.org/10.1111/j.1460-9568.1989.tb00352.x

[14] Josikins, PJosepherum, Oskykins, MountainTraveler, David Hedlund, Jositemp, and Graham. 2018. Time distortion. https://psychonautwiki.org/wiki/Time_distortion. Accessed October 31, 2018.

[15] Kenichi Kuriyama, Makoto Uchiyama, Hiroyuki Suzuki, Hirokuni Tagaya, Akiko Ozaki, Sayaka Aritake, Yuichi Kamei, Toru Nishikawa, and Kiyohisa Takahashi. 2003. Circadian fluctuation of time perception in healthy human subjects. *Neuroscience research* 46, 1 (2003), 23–31. https://doi.org/10.1016/S0168-0102(03)00025-7

[16] Yu-Hsuan Lin, Yu-Cheng Lin, Yang-Han Lee, Po-Hsien Lin, Sheng-Hsuan Lin, Li-Ren Chang, Hsien-Wei Tseng, Liang-Yu Yen, Cheryl CH Yang, and Terry BJ Kuo. 2015. Time distortion associated with smartphone addiction: Identifying smartphone addiction via a mobile application (App). *Journal of psychiatric research* 65 (2015), 139–145. https://doi.org/10.1016/j.jpsychires.2015.04.003

[17] William J Matthews. 2011. Stimulus repetition and the perception of time: The effects of prior exposure on temporal discrimination, judgment, and production. *PLoS one* 6, 5 (2011), e19815. https://doi.org/10.1371/journal.pone.0019815

[18] Stephen M Rao, Andrew R Mayer, and Deborah L Harrington. 2001. The evolution of brain activation during temporal processing. *Nature neuroscience* 4, 3 (2001), 317. https://doi.org/10.1038/85191

[19] Pei-Luen Patrick Rau, Shu-Yun Peng, and Chin-Chow Yang. 2006. Time distortion for expert and novice online game players. *CyberPsychology & Behavior* 9, 4 (2006), 396–403. https://doi.org/10.1089/cpb.2006.9.396

[20] Timothy Sanders and Paul Cairns. 2010. Time perception, immersion and music in videogames. In *Proceedings of the 24th BCS interaction specialist group conference*. British Computer Society, 160–167.

[21] Sofia Soares, Bassam V Atallah, and Joseph J Paton. 2016. Midbrain dopamine neurons control judgment of time. *Science* 354, 6317 (2016), 1273–1277. https://doi.org/10.1126/science.aah5234

[22] Chess Stetson, Matthew P. Fiesta, and David M. Eagleman. 2007. Does Time Really Slow Down during a Frightening Event? *PLOS ONE* 2, 12 (12 2007), 1–3. https://doi.org/10.1371/journal.pone.0001295

[23] Dan Zakay and Richard A Block. 2004. Prospective and retrospective duration judgments: an executive-control perspective. *Acta neurobiologiae experimentalis* 64, 3 (2004), 319–328. https://doi.org/10.3758/bf03209393