

Is the past farther than the future?

A replication and test of the time-expansion hypothesis based on event frequency

Qinjing Zhang^{1*}, Yoshitaka Masuda¹, Kohei Ueda¹, Kodai Toda¹, and Yuki Yamada²

¹Graduate School of Human-Environment Studies, Kyushu University, Fukuoka, Fukuoka,
Japan

²Faculty of Arts and Science, Kyushu University, Fukuoka, Fukuoka, Japan

*Corresponding author:

E-mail: zhang.qinjing.156@s.kyushu-u.ac.jp (QZ)

Commented [CC1]: Some suggested edits to the title to make it a little clearer (for me anyway – don't feel obliged to accept these edits)

Deleted: registered

Deleted: report

Deleted: demonstration

Deleted: of

Abstract

People sometimes feel events to be psychologically closer while farther at other times. Related to this, Caruso et al. (2013) reported the phenomenon of the Temporal Doppler Effect (TDE) in which people perceive the past farther than the future despite an equivalent objective temporal distance. They explained the TDE from the perspective of spatial-temporal metaphor. Alternatively, we assume that there is something asymmetrical between the past and the future, and this is related to the TDE. The asymmetry we focused on is the number of past and future events. Past events have already been experienced, while future events can only be imagined. This difference may affect how we perceive the number of events. In previous studies, the relationship between the number of changes (in our study, it is the number of events) and time perception has been investigated in a phenomenon called filled-duration illusion. It states that people tend to perceive durations with more changes (events) as longer than those with fewer changes. Analogous to this illusion, we hypothesize that in a long duration, such as a month or a year, the greater the number of events there are, the longer the estimated psychological distance is. In this research, we aim to create a direct replication of the TDE and provide our novel explanation for this phenomenon from the event frequency perspective.

Keywords: Temporal Doppler Effect, event frequency, psychological distance, filled-duration illusion

Commented [CC2]: **General note:** throughout the manuscript, as well as making comments regarding content, I have included some suggested language edits as tracked changes. These tracked changes are recommendations only and the authors should feel free to decline them where they disagree or feel that the edits reduce accuracy.

Deleted: that suggests

Deleted: that

Deleted: tend to feel

Deleted: though

Deleted: in

Commented [CC3]: Expand slightly to make clear

Commented [CC4]: This is a little vague

Commented [CC5]: I would suggest some rephrasing of these sentences to tighten the language and improve clarity. e.g. "Alternatively, the TDE might be explained by asymmetrical perceptions concerning the frequency of events between the past and future. Previous studies have shown that people tend to perceive durations with more events or changes as longer than those with fewer changes – a phenomenon termed the filled-duration illusion (FDI). If the TDE is related to the FDI, then over a long duration such as a month or a year, the number of events should positively predict the estimated psychological distance. In this research, we aim to create a direct replication of the TDE and test a novel explanation for this phenomenon from the event frequency perspective."

Introduction

While preparing for a conference in the coming week, we estimate the duration left to prepare for our presentation. Thinking about the tour last summer, we may perceive how long ago it took place. Although the ability to perceive and estimate time is fundamental in our daily life (Buhusi & Meck, 2005), our estimates of time are often inaccurate and do not correspond to objective time. For example, for second-level durations, Xuan, Zhang, He, and Chen (2007) reported that as the number of dots, stimulus size, luminance, and numbers increased, duration was perceived as longer. In addition, various factors such as emotion (Yamada & Kawabe, 2011), arousal (Schwarz, Winkler, & Sedlmeier, 2013), and temporal frequency (Yuasa & Yotsumoto, 2015) have been reported to affect subjective time.

Commented [CC6]: Suggest cutting these two sentences

Commented [CC7]: Suggest explaining this

Temporal Doppler Effect

For longer durations, it has also been suggested that our estimates of time are not always accurate. One example is The Temporal Doppler Effect (TDE). Caruso, Van Boven, Chin, and Ward (2013) reported that people tend to feel that the past is farther than the future, even when the objective temporal distance is the same. In their Study 1a, they asked participants to imagine either 1 month ago or 1 month later from that day, and asked the participants to report the target day's psychological distance. In Study 1b, they changed the duration from 1 month to 1 year. In Study 2, they used the reference of Valentine's Day and asked the participants to report the psychological distance from the fixed date. All the results of these studies indicated that the past feels farther than the future.

Deleted: think about

It has been suggested that our representations of time (e.g., past and future) may be based on metaphors of space and its movement. Generally, describing time requires spatial analogies and metaphors (Matlock, Ramscar, & Boroditsky, 2005). It is noted that temporal cognition relies heavily on spatial concepts as well (Casasanto & Boroditsky, 2008). While describing the duration of time, we use words like "long" or "far away," which are also used

to describe a physical distance. Additionally, it has been argued that temporal and spatial movement may be closely related to our behavior and temporal cognition. Miles, Nind, and Macrae (2010) reported that while thinking about the future, our body tends to lean forward, whereas while thinking about the past, it tends to lean back. It is also suggested that our thoughts about the future or past increase when observing vection stimuli that prompt the sensation of moving forward or backward, respectively (Miles, Karpinska, Lumsden, & Macrae, 2010). These studies indicate that spatial movement (especially forward and backward movement) is associated with our behavior and temporal cognition.

Based on these studies, Caruso et al. (2013) conducted Study 3 to provide evidence that TDE is caused by spatio-temporal metaphor-based movement in space. Study 3 examined whether virtual motion can moderate temporal asymmetries in the psychological distance. If TDE is caused by spatial movement based on spatio-temporal metaphors, virtual movement should influence the psychological distance. The results indicated that when the participants perceived moving forward, the past felt more distant than the future. In contrast, when they perceived moving backward, the future felt farther than the past. However, there was no significant difference. Due to this result, Caruso et al. (2013) proposed that the temporal asymmetry of psychological distance is formed by the perception that people are moving toward the future and moving away from the past. In other words, they proposed that approaching (i.e., future) events are felt to be psychologically closer while moving away (i.e., past) events are felt to be farther, even though the objective temporal distance is the same. In analogy to the well-known physical phenomenon of the Doppler Effect, Caruso et al. (2013) named this phenomenon the Temporal Doppler Effect. Aksentijevic and Treider (2016) also examined the TDE from the spatial movement perspective. They used not only imagined motion but also real motion. To avoid the existence of the anchoring effect, they introduced a control group and compared the real motion with imagined motion and the ego moving with

Deleted: the

Deleted: makes us feel like

Commented [CC8]: Some suggested rephrasing for clarity, but check it is accurate

Deleted: , and thoughts about the past increase when we feel like moving...

Commented [CC9]: Expand and clarify: no statistically significant difference between what exactly? And if there is was no evidence of a difference, was Caruso's conclusion (explained in the next two sentences) justified?

Commented [CC10]: This needs further explanation

Deleted: e

the time moving. Their results indicated that the TDE was only observed when participants move backward, regardless of past or future conditions.

The abovementioned explanations are from the perspective of spatial movement.

However, several studies have attempted to explain the TDE from perspectives other than spatial movements, such as personality (Gan, Miao, Zheng, & Liu, 2017), simulational fluency (Mrkva, Travers, & Van Boven, 2018), and development (McCormack, Burns, O'Connor, Jaroslawska, & Caruso, 2019). The present study aims to test an explanation of this phenomenon that arises from an alternative perspective of the asymmetry between past and future: event frequency.

Filled-duration illusion

The filled-duration illusion (FDI) occurs when people perceive a filled duration to be longer than an empty duration, even though both durations are objectively the same (Thomas & Brown, 1974; Wearden, Norton, Martin, & Montford-Bebb, 2007). Previous studies used intervening discrete elements (e.g., click sound, flash) as stimuli to fill the duration (Buffardi, 1971; Thomas & Brown, 1974). Some studies also used tasks, such as mental arithmetic, as the content of the filled duration (Burnside, 1971; Hicks, Miller, & Kinsbourne, 1976).

FDI has been mainly investigated for very short durations, such as milliseconds and seconds (e.g., Hasuo, Nakajima, Tomimatsu, Grondin, & Ueda, 2014; Wearden et al., 2007).

The existence of FDI-like phenomenon when changing the duration to hours, days, months or longer, is questionable. Analogous to the stimuli and tasks used in research of short durations, for longer durations, we assume that a duration's fullness is related to the number of events.

This means that the degree of fulfillment in past durations (i.e. event frequency) depends on the number of events people have experienced, while the degree of fulfillment in future durations depends on the number of scheduled events. In addition, the past has already occurred, therefore all experienced events contribute to the degree of fulfillment of a

Deleted: ,

Deleted: provide

Deleted: s

Deleted: another

Deleted: .

Deleted: The asymmetry can be seen in a number of events. To elucidate its relation to the TDE, we need to understand the phenomenon of

Deleted: .

Deleted: It refers to the fact that

Commented [CC11]: Because there is mixed evidence, or because there is no evidence? Suggest clarifying.

Commented [CC12]: Do you mean the perceived length of a duration or the extent to which a duration is filled with events? Perhaps clarify here so that the use of fullness is clearer later on

Commented [CC13]: Here and later do you mean fullness?

Deleted: It

Deleted: . It means that

duration. On the other hand, since the future has not occurred, only scheduled events contribute to the degree of fulfillment of a duration. **Therefore, we assume that there is an asymmetry of the number of events between past and future.** Thus, there would be more events in the past than the future, and the FDI-like effect would make us feel that a past duration is longer than a future duration, although both temporal distances are objectively equivalent.

Commented [CC14]: Why is this? I don't understand the basis of the assumption that the number of events that has already happened will be greater than the number of events that are scheduled or imagined for the future. In order for the TDE to be explained by the FDI, this is presumably a crucial auxiliary assumption? Is there previous literature supporting this assumption?

Aims of the present study

Findings that support our hypothesis have considered the estimation of the date of past events and how distant the events feel psychologically. We tend to estimate the date of an event in the past to be more recent or older than the actual date. This tendency is called telescoping (e.g., Janssen, Chessa, & Murre, 2006; Thompson, Skowronski, & Lee, 1988). Thompson et al. (1988) proposed that when we are unsure about the date of a specific event, we may use the number of events between the specific event and the present as a cue for date estimation. **As a consequence, when the number of events that occurred between the present and the date to be evaluated is greater, the date is estimated to be older, and vice versa.** Besides telescoping, Zauberman, Levav, Diehl, and Bhargave (2010) reported that the more event occurrences we can recollect between the present and the past, the more distant the events feel. These studies suggest that the number of intervening events is important in estimating the date of past events and the psychological distance from them. However, whether psychological distance about the future can be explained by the number of events has not been examined.

Deleted: sometimes

Deleted: This means
Deleted: that
Deleted: more the
Deleted: the older
Deleted: . W
Formatted: Font: Italic
Deleted: hile the fewer the events, the more recent the date is estimated to be

The present study aims **to replicate the TDE and test the overarching hypothesis that it arises from event frequency instead of spatial movement.** We will replicate the TDE directly by a registered report. To prevent the publication bias of replication research, we choose to do it as a registered report because pre-registration is not enough to prevent **such** bias (Ikeda,

Deleted: at creating a replication of
Deleted: providing novel explanations

Deleted: the

Xu, Fuji, Zhu, & Yamada, 2019). This will contribute to the robustness and transparency of the TDE research.

We plan to test two sets of hypotheses. First, we hypothesize that people will feel the past to be farther than the future although both durations are the same length, as in the previous original study (H1). In other words, we predict that Caruso et al.'s (2013) Study 1a and 1b will replicate successfully. Second, we expect people will have a greater number of events in the past than future (H2-1), because all the past events have been experienced, while only the scheduled events can be considered in the future. Furthermore, in analogy to FDI, in a relatively long time such as 1 month or 1 year, we hypothesize that the psychological distance will be farther when there are more events (H2-2). There will be a positive correlation between the number of events and psychological distance. If H2-1 and H2-2 are supported, we can provide a novel explanation of TDE from the perspective of event frequency. In other words, when people have more events in the past than the future, then people feel the past is farther than the future.

Study 1

Method

Key independent and dependent variable(s).

Independent variables.

Temporal direction (past, future). There are two temporal directions in our study: past and future. Similar to Caruso et al.'s (2013) study, temporal direction is a between-subject factor.

Event frequency. Event frequency is defined as the number of events that people have already experienced or will experience during a specific duration. We will use a Likert scale from 1 (not filled at all) to 10 (all filled up), and participants will report how many errands and events they have already experienced or will experience in 1 month (1 year in Study 2).

Commented [CC15]: I think you could cut these three sentences. There is no need to add a special justification for using the RR format. Instead, I would suggest including a concrete justification for why you are proposing two studies, with 1 month and 1 year timeframes. I'm finding the rationale for the two timeframes somewhat lacking at the moment (aside from the fact that it replicates Caruso 1a and 1b)

Deleted: Furthermore, we aim to provide our novel explanation of TDE focusing on event frequency instead of spatial movement.

Deleted: would

Deleted: be replicated in our study

Commented [CC16]: What is the evidence from previous literature to support the rationale for this hypothesis? It seems to me that this is a crucial auxiliary hypothesis because if the number of events in the past isn't greater than the number of events in the future then is the rationale for H2-2 still justified?

On the other hand, if there are stable individual differences in the *difference* between the number of (experienced) past and (imagined) future events, it seems to me you could use this to provide a more severe test of your overarching hypothesis, because participants with a greater difference (i.e. higher value of Past > Future) should exhibit a greater TDE, and participants who (for whatever reason) happen to show a reliable *negative* difference (i.e. Future > Past) should presumably show an opposite TDE? And if they didn't then maybe this would falsify the hypothesis that the event frequency is the determining factor?

Also: as I understand H2-2, it is a separate correlation for past, and a separate correlation for future? This wasn't clear from the design table either. Suggest clarifying.

Commented [CC17]: In relation to my previous comment, if the temporal direction is a between-subjects factor, then you wouldn't be able to test the more severe hypothesis I suggested based on the relative difference in event frequency between past and future, because you would only have measures of one or the other in each participant.

It may be worth considering a within-subjects design in which the order of future and past is counterbalanced (... [1])

Commented [CC18]: Confirm that this is the same or different methodology as Caruso (eg. Likert with same number of intervals etc) and explain why if there are any differences. Same comment for the psychological distance DV.

Dependent variable.

Psychological distance. Psychological distance refers to the distance people feel from the past or the future. In our studies, psychological distance will be measured using a Likert scale from 1 (a really short time from now) to 10 (a really long time from now). Participants will be asked to evaluate the psychological distance of exactly 1 month (1 year in Study 2) ago/later.

Participants.

Sample size and power analysis. Based on the power analysis elaborated below, 772 participants will be recruited for Study 1, which includes replication of Study 1a by Caruso et al. (2013). In their study, the effect size was calculated as Cohen's $d = 0.52$ and the sample size was 95. Nevertheless, a small sample size might overestimate the effect size.

Furthermore, in accordance with previous replication studies (Guo et al., 2020; Nitta, Tomita, Zhang, Zhou, & Yamada, 2018; Yonemitsu et al., 2020), we halved the effect size of Caruso et al.'s (2013) Study 1a and used Cohen's $d = 0.26$ to calculate the sample size required for our study. We conducted a power analysis at Cohen's $d = 0.26$, $\alpha = .05$, $1 - \beta = .95$ using G*Power 3.1 (Faul, Erdfelder, Lang, & Buchner, 2007) and pwr package 1.3-0 (Chamely, 2020) on R 4.0.5 (R Core Team, 2021). The power analysis result indicated that 386 participants per group (772 participants in total) were required to obtain a power of .95.

Recruitment and screening. All participants will be recruited online via Yahoo! Crowdsourcing Service.

Inclusion criteria include:

- Individuals between 18 to 99 years of age.
- Residents of Japan; as means of payment are only available in Japan.

Exclusion criteria include:

- Individuals under 18 or over 99 years of age.

Commented [CC19]: Are there any data-based exclusion criteria? E.g. incomplete data (if they only completed part of the questions?)

Taking the exclusion criteria into consideration, we intend to recruit up to 1000 participants to avoid the risk of insufficient sample size.

Procedure.

Participants will read instructions and give their informed consent before participating in the study. They will also be informed that they can withdraw their participation at any time. We will not collect any personal information except for gender and age. The collected data will be strictly protected. Once the informed consent is obtained, participants will fill the questionnaire.

Our studies will strictly follow the procedures used in Caruso et al.'s (2013) study, except for using crowdsourcing to recruit participants, and presenting the instructions and questionnaire in Japanese. Data will be collected using Google Forms.

After reading the instructions and giving their informed consent, participants will be instructed to report their gender and age. Then, participants will be requested to think back to precisely 1 month ago from the day of the study (past condition) or to think ahead to precisely 1 month from the day of the study (future condition) and report the target day's psychological distance, using a Likert scale from 1 (大変短い時間である: a really short time from now) to 10 (大変長い時間である: a really long time from now). Next, participants will report how much the past month (past condition) was filled with errands and events or how much the coming month (future condition) will be filled with errands and events using a similar scale from 1 (全く埋まっていなかった: not filled at all) to 10 (すべて埋まっている: all filled up).

Data analysis.

A two-sample *t*-test (past vs. future) will be conducted to compare the estimated psychological distance in the past condition and the future condition. Since this study

Commented [CC20]: Rather than stating an intended total sample size *before* exclusions, I suggest stating that data collection will continue until the minimum sample size indicated by the power analysis has been met *after* exclusions, regardless of the exclusion rate. Same comment for Study 2.

Commented [CC21]: Will the instructions make clear to participants what is an "event"? I can imagine this being interpreted very differently by different people. Can you provide an English translation of the exact instructions you will use in Supplementary Information?

Commented [CC22]: Would it be useful to have some form of attention check so that you could exclude responses made randomly (e.g. by bots or by participants just pressing buttons without thinking), or by people who didn't read the question? You could do this by including a question at the end that asks them to recall what the previous questions asked about, or perhaps a purely factual multiple-choice question to test that they are paying attention generally?

Along the same lines, if you are able to measure response times, it may be worth considering discarding data where people respond so quickly that they couldn't have read the question?

includes a replication for the TDE, we will analyze the data in the same way as Caruso et al. (2013). Subsequently, we will compare whether the event frequency differs in the past condition and the future condition based on a two-sample *t*-test. In addition, we will also conduct a correlation analysis between psychological distance and event frequency using Spearman's rank correlation coefficient. The criteria for confirming our hypothesis are as follows. For H1, we predict that psychological distance scores in the past condition will be significantly larger than in the future condition. Significant difference between the past condition and the future condition ($\alpha = .05$) indicates the acceptance of H1 as well as the success for the replication of Caruso et al.'s (2013) studies 1a and 1b. For H2-1, we predict that the event frequency scores in the past condition will be significantly larger than in the future condition. Significant difference between the past condition and the future condition ($\alpha = .05$) indicates the acceptance of H2-1. For H2-2, we predict that event frequency is related to psychological distance. A correlation analysis between event frequency and psychological distance will be performed and a significant positive correlation indicates the acceptance of H2-2.

Study 2

Method

Key independent and dependent variable(s).

The key independent and dependent variables are the same as those in Study 1.

Participants.

In Study 2, similar to Caruso et al.'s (2013) Study 1b, we only change the duration from 1 month to 1 year. The effect size in Caruso et al.'s Study 1b was calculated as Cohen's $d = 0.45$, and is larger than the effect size we used in our power analysis of Study 1 (Cohen's $d = 0.26$). Hence, we will also recruit the same number of participants in Study 2; that is, 772 participants will be recruited for Study 2 in the same way as in Study 1. We will also recruit

Commented [CC23]: I'm not sure yet if the disciplinary scope of this submission would be suitable for the journal Cortex (or if you are even considering Cortex yourself), but in case you are thinking of Cortex as a PCI RR-friendly outlet, keep in mind that alpha would need to be set to .02. A threshold of .05 is fine at all other PCI RR-friendly journals.

up to 1000 participants for the same reason as in Study 1. However, the participants will be limited to those who have not participated in Study 1.

Commented [CC24]: How will it be determined that participants did or did not participate in Study 1?

Procedure.

Study 2 will be conducted in the same way as Study 1, except for the change in the duration from 1 month to 1 year.

Commented [CC25]: Confirm here if the inclusion and exclusion criteria are the same.

Data analysis.

Study 2 will conduct the same analysis and definitions for acceptance of our hypotheses as in Study 1, except for the change in the duration from 1 month to 1 year.

Ethics

The ethics committee of Kyushu University approved this protocol (number: 2021-007). All participants will read instructions before participating in the study, with the understanding that they can withdraw their participation at any time and that we will protect participants' personal information. This study is conducted according to the principles expressed in the Declaration of Helsinki.

IS THE PAST FARTHER THAN THE FUTURE?

Question	Hypothesis	Sampling plan	Analysis Plan	Rationale for deciding the sensitivity of the test for confirming or disconfirming the hypothesis	Interpretation given different outcomes	Theory that could be shown wrong by the outcomes
Q1: Which is psychologically closer, future or past?	H1: People feel the past to be farther than the future as in the previous original study. (The same as Caruso et al.'s (2013) results).	772 participants (based on a power analysis) will be recruited in Study 1. Another 772 participants will be recruited in Study 2.	Similar to Caruso et al.'s (2013) Study 1a and 1b, we will use a two-sample <i>t</i> -test to compare the estimated psychological distance in the past condition and future condition.	Significant difference between the past condition and the future condition ($\alpha = .05$) indicates the acceptance of H1 and the replication success of Caruso et al.'s (2013) Study 1a (when duration is 1 month) or 1b (when the duration is 1 year).	If H1 is not supported, there may be two reasons for it. First, the results of psychological distance may be affected by the recruitment method of participants (i.e., crowdsourcing). Second, there is a possibility that the TDE does not exist or only exists under very limited conditions.	Q1 and H1 aimed to replicate Caruso et al.'s (2013) study directly. Therefore, the theory could be proven wrong if the outcome is not as expected.
Q2-1: Which has more events, future or past?	H2-1: People have a greater number of events in the past than in the future.		We will use a two-sample <i>t</i> -test to compare whether the event frequency differs in the past	Significant difference between the past condition and the future condition ($\alpha = .05$) indicates the	If H2-1 and H2-2 are not supported, it suggests that the event frequency is not an appropriate explanation for the	We are not at contradiction with Caruso et al.'s (2013) explanation as our aim is to provide a different perspective.

			condition and the future condition.	acceptance of H2-1.	TDE. If H2-2 is supported but H2-1 is not supported, we cannot explain TDE by event frequency. However, there might be some distortion of time estimation, which is based on the FDI-like effect.	another explanation for it, regardless of spatial-temporal metaphor.
Q2-2: Do the number of events affect the psychological distance in the future condition and the past condition?	H2-2: When there are more events, the psychological distance is farther.		We will conduct a correlation analysis between psychological distance and event frequency using Spearman's rank correlation coefficient.	Significant positive correlation between psychological distance and event frequency indicates the acceptance of H2-2.		

Commented [CC26]: Is this one correlation analysis each for future and past conditions, or a combined analysis?

References

- Aksentijevic, A., & Treider, J. M. G. (2016). It's all in the past: Deconstructing the temporal Doppler effect. *Cognition*, *155*, 135–145. <https://doi.org/10.1016/j.cognition.2016.07.001>
- Buffardi, L. (1971). Factors affecting the filled-duration illusion in the auditory, tactual, and visual modalities. *Perception & Psychophysics*, *10*(4-B), 292–294. <https://doi.org/10.3758/BF03212828>
- Buhusi, C. V., & Meck, W. H. (2005). What makes us tick? Functional and neural mechanisms of interval timing. *Nature Reviews Neuroscience*, *6*(10), 755–765. <https://doi.org/10.1038/nrn1764>
- Burnside, W. (1971). Judgment of short time intervals while performing mathematical tasks. *Perception & Psychophysics*, *9*(5), 404–406. <https://doi.org/10.3758/BF03210238>
- Caruso, E. M., Van Boven, L., Chin, M., & Ward, A. (2013). The Temporal Doppler Effect: When the Future Feels Closer Than the Past. *Psychological Science*, *24*(4), 530–536. <https://doi.org/10.1177/0956797612458804>
- Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition*, *106*(2), 579–593. <https://doi.org/10.1016/j.cognition.2007.03.004>
- Champely, S. (2020). pwr: Basic Functions for Power Analysis. R package version 1.3-0. <https://CRAN.R-project.org/package=pwr>
- Faul, F., Erdfelder, E., Lang, A. G., & Buchner, A. (2007). G* Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior research methods*, *39*(2), 175-191. <https://doi.org/10.3758/BF03193146>
- Gan, Y., Miao, M., Zheng, L., & Liu, H. (2017). Temporal Doppler Effect and Future Orientation: Adaptive Function and Moderating Conditions: Future Orientation and Doppler Effect. *Journal of Personality*, *85*(3), 313–325. <https://doi.org/10.1111/jopy.12242>

- Guo, W., Liu, H., Yang, J., Mo, Y., Zhong, C., & Yamada, Y. (2020). Stage 2 Registered Report: How subtle linguistic cues prevent unethical behaviors. *F1000Research*, 9, 996. <https://doi.org/10.12688/f1000research.25573.2>
- Hasuo, E., Nakajima, Y., Tomimatsu, E., Grondin, S., & Ueda, K. (2014). The occurrence of the filled duration illusion: A comparison of the method of adjustment with the method of magnitude estimation. *Acta Psychologica*, 147, 111–121. <https://doi.org/10.1016/j.actpsy.2013.10.003>
- Hicks, R. E., Miller, G. W., & Kinsbourne, M. (1976). Prospective and Retrospective Judgments of Time as a Function of Amount of Information Processed. *The American Journal of Psychology*, 89(4), 719–730. <https://doi.org/10.2307/1421469>
- Ikeda, A., Xu, H., Fuji, N., Zhu, S., & Yamada, Y. (2019). Questionable research practices following pre-registration. *Japanese Psychological Review*, 62(3), 281–295. https://doi.org/10.24602/sjpr.62.3_281
- Janssen, S. M. J., Chessa, A. G., & Murre, J. M. J. (2006). Memory for time: How people date events. *Memory & Cognition*, 34(1), 138–147. <https://doi.org/10.3758/BF03193393>
- Matlock, T., Ramscar, M., & Boroditsky, L. (2005). On the Experiential Link Between Spatial and Temporal Language. *Cognitive Science*, 29(4), 655–664. https://doi.org/10.1207/s15516709cog0000_17
- McCormack, T., Burns, P., O'Connor, P., Jaroslawska, A., & Caruso, E. M. (2019). Do children and adolescents have a future-oriented bias? A developmental study of spontaneous and cued past and future thinking. *Psychological Research*, 83(4), 774–787. <https://doi.org/10.1007/s00426-018-1077-5>
- Miles, L. K., Karpinska, K., Lumsden, J., & Macrae, C. N. (2010). The Meandering Mind: Vection and Mental Time Travel. *PLOS ONE*, 5(5), e10825. <https://doi.org/10.1371/journal.pone.0010825>

- Miles, L. K., Nind, L. K., & Macrae, C. N. (2010). Moving Through Time. *Psychological Science*, 21(2), 222–223. <https://doi.org/10.1177/0956797609359333>
- Mrkva, K., Travers, M., & Van Boven, L. (2018). Simulational fluency reduces feelings of psychological distance. *Journal of Experimental Psychology: General*, 147(3), 354–376. <https://doi.org/10.1037/xge0000408>
- Nitta, H., Tomita, H., Zhang, Y., Zhou, X., & Yamada, Y. (2018). Disgust and the rubber hand illusion: A registered replication report of Jalal, Krishnakumar, and Ramachandran (2015). *Cognitive Research: Principles and Implications*, 3. <https://doi.org/10.1186/s41235-018-0101-z>
- R Core Team (2021). R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL <https://www.R-project.org/>
- Schwarz, M. A., Winkler, I., & Sedlmeier, P. (2013). The heart beat does not make us tick: The impacts of heart rate and arousal on time perception. *Attention, Perception, & Psychophysics*, 75(1), 182–193. <https://doi.org/10.3758/s13414-012-0387-8>
- Thomas, E. C., & Brown, I. (1974). Time perception and the filled-duration illusion. *Perception & Psychophysics*, 16(3), 449–458. <https://doi.org/10.3758/BF03198571>
- Thompson, C. P., Skowronski, J. J., & Lee, D. J. (1988). Telescoping in dating naturally occurring events. *Memory & Cognition*, 16(5), 461–468. <https://doi.org/10.3758/BF03214227>
- Wearden, J. H., Norton, R., Martin, S., & Montford-Bebb, O. (2007). Internal clock processes and the filled-duration illusion. *Journal of Experimental Psychology: Human Perception and Performance*, 33(3), 716–729. <https://doi.org/10.1037/0096-1523.33.3.716>
- Xuan, B., Zhang, D., He, S., & Chen, X. (2007). Larger stimuli are judged to last longer. *Journal of Vision*, 7(10), 2–2. <https://doi.org/10.1167/7.10.2>
- Yamada, Y., & Kawabe, T. (2011). Emotion colors time perception unconsciously. *Consciousness and Cognition: An International Journal*, 20(4), 1835–1841. <https://doi.org/10.1016/j.concog.2011.06.016>

Yonemitsu, F., Ikeda, A., Yoshimura, N., Takashima, K., Mori, Y., Sasaki, K., Qian, K., & Yamada, Y. (2020). Warning ‘Don’t spread’ versus ‘Don’t be a spreader’ to prevent the COVID-19 pandemic. *Royal Society Open Science*, 7(9), 200793.

<https://doi.org/10.1098/rsos.200793>

Yuasa, K., & Yotsumoto, Y. (2015). Opposite Distortions in Interval Timing Perception for Visual and Auditory Stimuli with Temporal Modulations. *PLOS ONE*, 10(8), e0135646.

<https://doi.org/10.1371/journal.pone.0135646>

Zauberman, G., Levav, J., Diehl, K., & Bhargave, R. (2010). 1995 Feels So Close Yet So Far: The Effect of Event Markers on Subjective Feelings of Elapsed Time. *Psychological Science*, 21(1), 133–139. <https://doi.org/10.1177/0956797609356420>

Acknowledgements

We would like to thank Editage (www.editage.com) for English language editing.

Authors’ contributions

CRedit Statement for Stage 1 manuscript

Conceptualization: QZ, YM, KU, KT, YY; Funding acquisition: YY; Methodology: QZ, YM, KU, KT; Project administration: YY; Supervision: YY; Visualization: QZ, YM, KU, KT; Writing - original draft: QZ, YM, KU, KT, YY

Funding

This research is supported by JSPS KAKENHI: JP16H03079, JP17H00875, JP18K12015, JP20H04581, and 21H03784.

In relation to my previous comment, if the temporal direction is a between-subjects factor, then you wouldn't be able to test the more severe hypothesis I suggested based on the relative difference in event frequency between past and future, because you would only have measures of one or the other in each participant.

It may be worth considering a within-subjects design in which the order of future and past is counterbalanced. You could keep the design as it is now but just add an additional condition for each participant (so if they did future first then they do past second; if they did past first they do future second). That way you could use the data from the first session in the planned between-subjects analysis to provide a close replication of Caruso 2013, while also having data from future and past sessions within each participant available to be able to measure the difference, and hence the severe hypothesis that the difference in event frequency between future and past predicts the polarity and magnitude of the individual's TDE.

|

▲