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Disorientation and time distortions during the metro commute: an analysis of 456 responses to a questionnaire distributed in real-time on Twitter during traffic disruptions in the Paris area

Authors: Bastien Perroy¹, Umer Gurchani¹, Roberto Casati¹

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Data availability statement: All relevant data can be accessed on this OSF archive (anonymized for peer-review): https://osf.io/dkwmz/?view_only=8928b5ebaadf489687e1ef2a06579457

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Intro

Public transport users are susceptible to experiencing temporal disorientation when traffic disruptions occur:

“I am upset because, despite a very comfortable 30-minute margin, the RER B did not reach its destination on time. Because of this delay, I missed my train by one minute. I have been taking this train every day for the last 10 days to go to my father's bedside. He will die soon. He is in intensive care at the Lille hospital and has no chance of recovery. Consequently, missing the train is fraught with consequences. Despite the attempts of the SNCF staff, it was impossible to exchange the ticket for the next train, as they were all full (due to the Lille flea market). As a result, I will not see my father

today but tomorrow, if he is still alive. What hurts me the most is that I had promised him that I would come. He understands despite his condition and in fact, he won't wait for me today. I never thought I would experience such despair because of an RER trip. And yet I love taking public transport. Until now.”

This testimony was given by one of our respondents in real time on the Paris rapid transit system, following his participation in our study. The traveller mentions that he took a “30-minute margin”, which we can interpret as a sign of the time pressure he felt to arrive in time to catch the crucial connection in his journey: he had made a promise and wanted to make sure he didn't miss his rendezvous. With the stress and subsequent confusion we can assume of the moment he realised he wouldn't reach his train before it departs, also comes disorientation: anxiety, regret, and hopelessness about his near future and past. As it happens, he is afraid that he may have missed one of the last opportunities to see his dying father, which makes him feel “such despair”, unexpected of a train travel disruption.

During sudden shocks, time can seem to get ruptured, and the flawless integration of the past, the present, and the future into one cohesive whole seems to be no more (Fuchs, 2013). Temporal disorientation partly comes from the severance induced by such unexpected events between ourselves and a future onto which we cling when we act (Game, 1997). Episodes of disorientation can be mild, merely conscious metacognitive feelings about being off from just a bit during navigation (Fernández Velasco, 2022), but also linger as existential feelings (Stegmaier, 2019), incorporating “a sense of being unable to depend on others” (Ratcliffe, 2021). With temporal disorientation comes a host of time distortions, such as an altered sense of the passage of time or of temporal distances, phenomena which have been investigated through isolation studies or life-shattering events like the Covid-19 pandemic (van Wassenhove, 2022). Temporal disorientation is an experiential commonality of problematic circumstances. Consequently, we can apprehend traffic disruptions as among the many forms of crises that people face throughout their lives, and in which their belonging to a familiar course of events breaks down. In this paper, we aim at providing an experimental light on the overarching disorientation experienced by travellers in case of service disruptions by breaking the phenomenon down in terms of its associated time distortions.

Time slows down during existentially disrupting periods like the Covid-19 pandemic (Chaumon et al., 2022) or economic crises like the one in Argentina in 2002 (Flaherty et al., 2005), and is usually associated with a host of negative emotions (Martinelli et al., 2021). Alternative terminology for passage of time judgements includes describing the fast-slow divide as *compression* and *protraction* separated by a state of *synchrony*, in the sociological literature (e.g. Flaherty, 2018; Dyer, 2021); or construing slow time as *dilation* (Wittman et al., 2015), or as *expansion* (Cravo et al., 2022) through a host of phenomenological features in factor analysis. The phenomenon under scrutiny is the same in all instances: passage of time judgements are introspective judgements, either prospective (about the present) or retrospective (about previous experiences), that compare the “self in time” with “a representation of external time”, and as such seem to vary mainly depending on the emotions of the introspective context (Droit-Volet, 2019). Alternatively, some suggest more radically that while a judgement of a slow passage of time is a recall of a present experience (e.g. of a monotonous or boring event),

fast time would be grounded in an inference (of a previous absence of attention cues dedicated to the passage of time), entailing an ontological rupture in the linear spectrum between fast and slow (Wearden, 2015).

Passage of time judgements are often studied alongside temporal distance judgements (e.g. Chaumon, 2022), the latter being short or long feelings of time expressing whether an event feels noticeably close or distant in time (Zauberman et al., 2010) or whether e.g., a period has an outsized proportion in one's mental timeline (Ogden and Piovesan, 2022). Both passage of time judgements and temporal distance judgements seem to express (rather than represent objectively) something about the subject's embodiment in her environment, which is typical of metacognitive feelings (Proust, 2015). The distinction between them lies in temporal distance judgements relying more heavily on abstract processes such as perspective-taking and counterfactuals (Liberman and Trope, 2014). Conceiving the experience of the passage of time as a temporal metacognitive feeling is congruent with Flaherty's conceptual move in his theory of the passage of time (2018). From a previous conception associated with stimulus complexity in the environment, Flaherty rather proposes that the passage of time is dependent upon the density of experiences of the subject per standard temporal unit. By contrast with the previous stimulus-based view, this model outlines the expressive nature of time judgements through the contrast between the subject's embodiment and a socially constructed time frame of reference.

Flaherty's model entails two claims about public transport service disruptions. On the one hand, while time should slow down as a function of the problematic aspect of the situation, the passage of time particular to a given experience should also accelerate over time as episodic memory deteriorates. In line with this claim, a recent study found that the fewer autobiographical memories are activated for a given experience, the faster the experience seems to have passed (Kosak, Kuhbandner, and Hilbert, 2019). In our case, we should find that the longer the time interval separating our respondents from the disruption they recollect, the faster time should have seemed to pass, with overall judgements skewed towards time passing more slowly. On the other hand, Flaherty (2018) suggests that quantitative applied studies like ours could shed light on to what extent people exercise temporal agency in deciding their circumstances to alter their experience of time, rather than passively accept their experience of time as a result of the problematic circumstances they face. In line with this idea, Dyer (2021) claims that the temporal agency of subway riders is often overlooked as travellers seem to perform various activities in the metro to make time pass faster due to a longing for synchronicity, i.e. a more normal experience of the passage of time. A wealth of time perception studies on public transport found that travellers tend to overestimate their past travel length at each stage of a multimodal trip (Meng, Rau, and Mahardhika, 2018), even more so in heavy rail systems like a subway trip, compared to lighter tram or bus travels (Brands et al., 2022). Due to the association between overestimated duration judgements and the slow passage of time judgements on timescales longer than 30 seconds (Droit-Volet, Trahanias and Maniadakis, 2017), existing quantitative evidence entails that the passage of time in the metro is already judged as slow even when there is no disruption. And due to the anxiety-inducing nature of delays (Cheng, 2010), we can expect time to be judged slowing down even more during disruptions. Seeing the metro as a place of time dilation, in general, is also congruent with other descriptions of the varying activities performed by travellers like reading, daydreaming or texting that are performed to counterbalance the lack of social interaction and

the boredom characteristic of the commute (Singleton, 2017). If as Dyer (2021) claims, it is true that travellers act within their travel mainly as a way to modulate their temporal experience, then we should see travellers reorienting themselves during disruptions experience a faster passage of time compared to those who don't.

Finally, an interesting variable is *temporal vertigo*, documented as a feature of severe crises like the Covid-19 pandemic through a variety of conflicting time feelings (Alatrany et al., 2022), like “when urgency is experienced at the cliff edge of sudden rupture” during the Greek economic crisis of the 2010s (Knight, 2022). In such crises, time dilation can in fact hide distorted bi-modal judgements of the passage of time and temporal distances, i.e. both slow and fast time passage, or both short long distances to watershed events (for Covid-19 reporting this phenomenon see Ogden, 2020; Ogden and Piovesan, 2022; Kosak, Schelhorn and Wittman, 2022; [authors]). In our case, it might be that arrival at the destination could be perceived as farther away due to increased uncertainty to make it in time, but also closer to one as one feels she was just a few steps away from it, clinging so to speak to the counterfactual scenario of an undisrupted trip. Imagination can modulate temporal feelings through their frames of reference so that for instance, in a similar situation in which one misses the boarding of a plane by only 5 minutes, one would feel more regret than someone missing it by 30 minutes (Tversky and Kahneman, 1982). It might be that some travellers experience both faster and slower passage of time, or both longer and shorter feelings of distance, at times, during the disruptions. The uncanniness of a whirling succession of time distortions might aggravate the traveller's disorientation per se, which would result in increased disorientation.

Studies investigating public transport disruptions have stressed that the degree of tolerance for delays varies with service quality, e.g. clarity of information addressed to passengers (Cheng and Tsai, 2014). The decision whether to reorient oneself or not is driven by both individual factors like navigational expertise, or situational ones like time constraints and perception of service recovery time (Adel , 2019). Navigating a public transport network traditionally involves balancing uncertainty and wait times in the valuation of route choices (Shelat, Cats, and van Lint, 2021). Alongside temporal judgements, our study also aims at capturing individual and situational variables that modulate the superseding disorientation. Railway disruptions are operationally diverse (Golightly and Dadashi, 2017). They primarily vary in terms of causes (e.g., as they're termed by transport operators: "forgotten luggage", "people on the tracks") and consequences (most importantly, whether traffic is only slowed down or completely interrupted). Precise estimates of the time required to return to normal service may or may not be provided. The underlying reasons associated with time pressure are also diverse: being late for work or picking up children from nursery could be classified as a form of social anxiety, but missing a connection that would allow one to visit a suffering relative is another issue with its own phenomenology, as it can also incorporate a grieving experience. Disruptions also generate shared social affects (e.g. frustration) and dispositions, e.g. one might be inclined to follow a herd of experienced commuters taking an alternative route (Bissell, 2010). Not knowing why the train has stopped, disoriented travellers may gauge confusion in each other's gazes, waiting for relevant epistemic cues to emerge. The complexity of the episodes of disorientation we want to study is such that the ecology would be very hard to reproduce in a lab or virtual environment. Unfortunately, due to the inherent unplanned

nature of traffic disruptions, it is also difficult to distribute psychometric questionnaires on a large scale with traditional distribution methods. New and innovative methods are required to reach out to participants when they are experiencing the traffic disruption.

The aim of this study is then twofold. On the one hand, we describe a novel methodological approach to the psychology of traffic disruptions with the distribution in real-time of online questionnaires to people interacting with disruption announcements on social media. We claim this not only makes the distribution more efficient but also improves data quality by allowing researchers to recruit respondents presently undergoing disruptions. By extension, we suggest this social-media distribution method could be applied to the psychological study of many other crises in which one would like to investigate subjective experiences and control for possible mnemonic biases. To this end, we include both participants currently facing the disruption, as well as those for which the disruption is over at various recollection time points, and we focus particularly on the effects of recollection delay on other variables.

On the other hand, we use passage of time judgements and temporal distance judgements to test a number of hypotheses. Traffic disruptions can be considered unexpected problematic circumstances. Therefore, they should have a similar structure of disorientation as other unexpected crises, which can range in scale from individual-level spatial disorientation to mass-scale crises such as pandemics. Time should slow down, and distances elongate. Due to the erosion of episodic memory, we expect the experience being remembered to seem to have passed faster over time. Conflicted time feelings, known as vertigo, e.g., both fast and slow passage of time, at times, are expected to exacerbate disorientation. Finally, we hypothesise that travellers exercise agency to make time pass faster.

Methods

Distribution strategy

We recruited participants on Twitter based on their interactions with traffic disruption announcements in the Paris area. Since 2012, each of the city's 14 metro and 5 RER lines has its own Twitter account. (A RER train is a suburban type of metros, connecting the inner districts of Paris with its suburbs.) Operators from within command centres feed these Twitter accounts with information as soon as they make announcements on other media, e.g. audio announcements, alerts on screens on platforms, or on smartphone applications, among others. As of December 2022, there are 192 800 followers of the RER A account, the busiest suburban transit line in Europe. Over the years, commuters have been accustomed to being able to follow and even formulate requests for direction on these Twitter accounts. Whenever a user liked, retweeted, or replied to an announcement within 50 minutes of the disruption tweet, they received a tweet within ten minutes inviting them to participate in the study. The distribution was arbitrarily restricted to 50 minutes to maximise the probability of reaching respondents still on the network, and took place between August and October 2022. 456 participants out of

the initial 620 who consented to participate in the study, all 18 or older, completed the entire questionnaire and reported experiencing recently a traffic disruption.

By sending questionnaires following social-media interactions on traffic disruptions announcements, it is easy to contact thousands of people and gather a relevant sample with much less cost and effort. Traffic disruptions, by definition, can't be identified before they occur. Face-to-face administration of the survey would have been serial rather than parallel, and surveyors would have lost time to reach any disruption site. Disruptions vary in severity and may be over by the time surveyors would have finally gotten on site, while another, possibly more important disruption had occurred elsewhere. In contrast, automated online distribution permits sending of several hundred questionnaires whenever and wherever a disruption occurs and within a timeframe of just a few minutes. In sum, the first advantages of social-media distribution are *targeted precision, scalability, and efficiency*.

Our sample was relatively representative (Mairie de Paris, 2015) with $\approx 49\%$ male and $\approx 47\%$ female respondents, and with a mean age of ≈ 34 and a median age of 31. However, $\approx 98\%$ of our respondents take the metro system at least several times a week and $\approx 58\%$ were going to work during the disrupted travel they reported. This may be due to experienced morning rush hours commuters being more inclined to rely on Twitter to get information. Additionally, compared to the actual metro population, our sample had a much higher percentage of people with a master's or doctoral degree ($\approx 57\%$ of our respondents had achieved a master's or doctoral degree) and a lower percentage of people over 64 ($\approx 1.3\%$ in our sample vs $\approx 8\%$ in the metro). We then have 3 noteworthy under-represented groups in our sample: the elderly, infrequent (thus non-expert) travellers, and travellers with a low level of general education.

A notable aspect of our data quality is the freshness of the disruptions in the minds of our respondents. The majority of our respondents fulfilled the questionnaire less than two days after the reported disruption occurred. A noteworthy number of respondents ($n = 96$, or $\approx 21\%$ of our sample) even fulfilled the survey while they were still in the disruption. Gathering a subset of respondents that are still in the disruption hasn't been achieved by any previous public transport study. Yet, disrupted travellers often have subsequent waiting phases in the remainder of their trip, which leave them enough time to fill out surveys with their smartphones (e.g., a tweet replying to the invitation to participate in the study reads "*It's done! I took the opportunity of the nightmare on line 7 to answer the questions*"). This subsample allows us to test whether mnemonic biases may be involved in recollecting the experience. The second main advantage, thus, is the *reduced inertia* between experience and survey administration, which we claim is not just a gradual improvement in data quality but a categorical one, as disruptions can be studied as *presently happening* for respondents.

No personal data which would permit identification was recorded at any stage of the study. Twitter user IDs (which are not personal names) were retrieved so that to make sure each user could receive an invitation to participate in the study only once, even if they were to interact repeatedly with announcements. There was no financial compensation for completing the questionnaire, which was hosted on Qualtrics. The questionnaire was fully anonymous, and participants completed a written consent form online before being admitted to the study. Our

study followed the ethical procedures for approval at our institution for research involving human participants. The Pôle Éthique of the Institut des Sciences Biologiques (INSB) of the Centre National de la Recherche Scientifique (CNRS) waived all ethical approval for fully anonymous questionnaires. The study has been conducted according to the principles expressed in the Declaration of Helsinki.

Questionnaire design

Passage of time and temporal distance judgements were central to our questionnaire design. We not only wanted to gather them but also permit our respondents to express conflicting feelings about them, so we decided to retrieve the corresponding components from an instrument used to measure temporal disorientation during the Covid-19 pandemic [authors]. These components were validated initially through a 3-step process involving one explanatory and two confirmatory analyses (Kyriazos, 2018) and were aimed at better capturing the bi-modality of these judgements. Both the passage of time component (henceforth, PoT) and the perceived temporal distance component (TD) were composed of 3 questions, one querying whether, at times, time passes noticeably slower during the disruption; one querying whether, at times, time passes noticeably quickly during the disruption; one querying whether overall, time passes slowly/quickly during the disruption. The three temporal distance questions were framed akin to the questions about passage of time, but the reference point was whether the destination feels temporally farther away or closer during the disruption. Contrary to previous studies in which distance judgements are probed retrospectively for past periods (e.g. Ogden and Piovesan, 2022), here we ask about one's feeling of distance (or closeness) towards arriving at the destination, which in the context of the disruption is a future event still shrouded in uncertainty. These questions were answered with a 7-point Likert scale ranging from "strongly agree" to "strongly disagree" for the "at times" questions, and "very slowly" or "much farther away" to "very quickly" or "much closer" for the "overall" questions.

Alongside age, gender, and education, the following characteristics were retrieved: frequency of navigation with metro/RER lines; line on which the disruption occurred; when the disruption occurred relative to completing the survey; whether respondents were in a train, in a station, or elsewhere in the city when they first learned about the disruption; the severity of the disruption; whether one chose to wait or decided to reorientate, and whether this choice was advised by the transport operator; and finally what was the underlying reason for the travel.

In terms of continuous quantitative variables, we queried eight items with sliders from 0 to 10, accepting one decimal increment. We asked for a general level of satisfaction with metro and RER lines, a general level of confusion during the disruption, and the following six psychological variables: perceived pressure to get in time to destination, stress, anxiety, discomfort due to crowding, helplessness, and trust in the directions administered by the transport operator during the disruption.

Confusion (perplexity) is a central feature of spatial disorientation (Fernández Velasco, 2022), and disorientation can be conceptualised as a subcategory of confusion about pieces of information related to orientation and navigation. Congruent with this view, Knight (2022) describes temporal disorientation as a "dizzying confusion". Disorientation can have complex and heterogeneous affective profiles, as exemplified by our introductory narrative. We use

confusion in this study as a necessary yet non-sufficient proxy for disorientation: someone who is not confused is probably not feeling disoriented.

All eight continuous quantitative variables, as well as the 6 PoT and TD questions, were examined through a factor analysis and returned with a KMO-index of 0.82 and a significant Bartlett's test of sphericity, $\chi^2(14) = 1198.49$, $p < 0.001$. Three factors were retained after varimax rotation as they were above one eigenvalue each, namely: *Uneasiness* (composed of *Pressure, Stress, Anxiety, Discomfort, and Helplessness*, with a lowest factor loading of 0.53 and Cronbach $\alpha = 0.83$); *Temporal Distance* (composed of *short time, long time, and overall distance*, with a lowest factor loading of 0.70 and Cronbach $\alpha = 0.84$); and *Passage of Time* (composed of *slow time, fast time and overall time*, with a lowest factor loading of 0.50 and Cronbach $\alpha = 0.71$). Cronbach alphas were all above 0.7. Both TD and PoT were retrieved from a previously validated instrument Finally anxiety and crowding were previously described as being strongly related in transit (Cheng, 2010). Hence, this set of 3 factors seemed satisfactory in encapsulating three crucial phenomenological features of traffic disruptions. Situational aspects of the psychology of traffic disruptions were encapsulated in the *uneasiness* factor; perceived lengthening or shortening of distance to the destination was encapsulated in the *Temporal Distance* factor; perceived acceleration or slowing of the passage of time during the disruption was encapsulated in the *Passage of Time* factor. As bi-modal passage of time judgements were documented in studies investigating the Covid-19 pandemic (Ogden, 2020), we suspected that these factors were probably not normally distributed. Three Shapiro-Wilk tests indicated that their distributions departed indeed significantly from normality (Uneasiness: $W = 0.92$, $p < 0.001$; TD: $W = 0.85$, $p < 0.001$; PoT: $W = 0.81$, $p < 0.001$), which was confirmed by visual exploration. Additionally, confusion, which wasn't a factor from factor analysis but a variable we wanted to monitor to track a minimal condition of disorientation, wasn't normally distributed either ($W = 0.96$, $p < 0.001$). Consequently, we settled on non-parametric tests in the forms of Kruskal-Wallis tests and post-hoc Mann-Whitney U tests to investigate the effects of our categorical variables on our our three extracted factors as well as the confusion variable. We also report Vandekar's S (Vandekar et al., 2020) as a robust effect size metric, which is based on Cohen's d, indicating a low effect size with $S \approx 0.1$, a medium effect size with $S \approx 0.25$ and a large effect size with $S \approx 0.40$. Finally, in order to investigate the relationship between time distortions and the disorientation associated with these traffic disruptions, we conducted a multivariate regression analysis between PoT and TD as independent variables and confusion as the dependent variable.

Results

In this section, we report the effects associated with recollection delay, the socio-demographic imbalances described previously, and all other significant effects, in this order. We then analyse how conflicted time feelings (e.g., both fast and slow passage of time, at given times, during the disruption) interact with recollection delays and disorientation, and whether time distortions can predict confusion altogether through multivariate regression analysis.

Figure 1 shows the distribution of responses as well as means and 95% bootstrap confidence intervals for both TD and PoT depending on when our respondents filled out our survey relative to the disruption they experienced. Examination of Figure 1 indicates that most of our respondents reported that their destination felt noticeably temporally farther away during the disruption, as well as time passing slower. Compared to all other respondents, people filling the survey during the disruptions reported significantly different perceived temporal distances ($\chi^2(2) = 7.85, p < 0.01$), passage of time ($\chi^2(2) = 5.23, p = 0.022$), uneasiness ($\chi^2(2) = 9.98, p < 0.01$) and confusion ($\chi^2(2) = 13.86, p < 0.01$). Post-hoc Mann-Whitney U tests confirmed significantly longer perceived distances ($p < 0.01, S = 0.17$) slower passage of time ($p < 0.01, S = 0.13$), increased uneasiness ($p < 0.01, S = 0.12$), and increased confusion ($p < 0.01, S = 0.17$) for respondents still navigating the network.

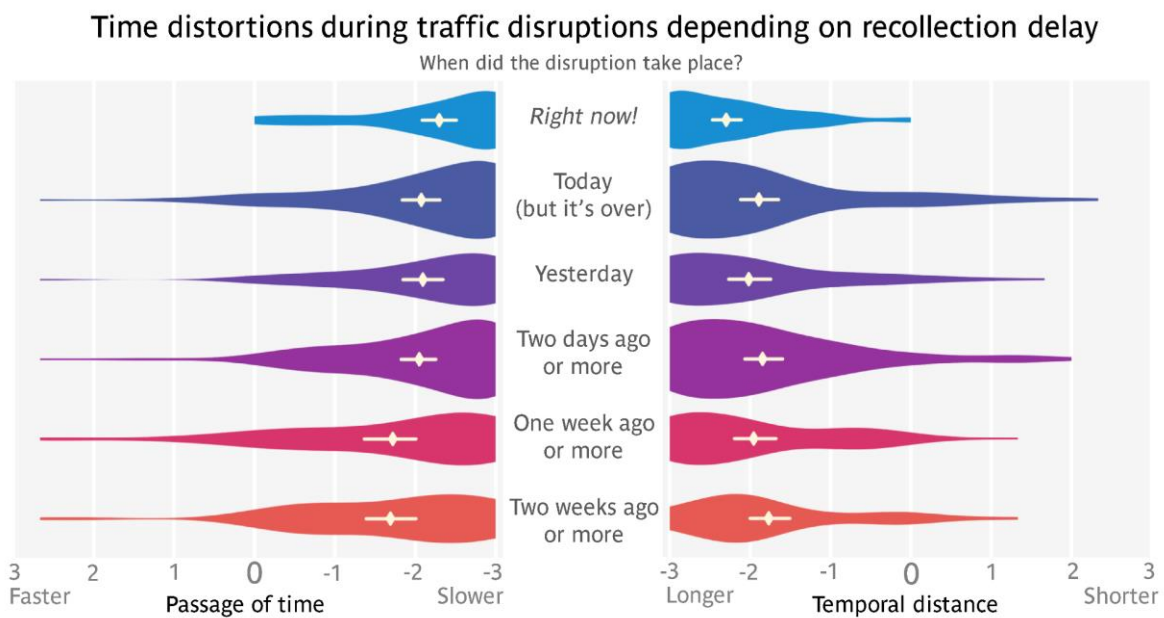


Figure 1: violin plots with means and 95% CI (bootstrap) for each survey completion time compared to the disruption. Respondents were asked to pick the most fitting estimate. The surface area of the violins is proportional to the number of respondents per category (kernel density plot).

There were no significant differences between education degrees for PoT ($\chi^2(5) = 2.66, p = 0.62$), TD ($\chi^2(5) = 4.22, p = 0.38$), and uneasiness ($\chi^2(5) = 1.71, p = 0.79$); but a very significant one in terms of confusion ($\chi^2(5) = 13.52, p < 0.001$). We assumed a level of studies corresponding to a doctoral degree would lead to lessened confusion during disruptions against respondents holding non-doctoral degrees, which a post-hoc Mann-Whitney U test confirmed ($p < 0.001, S = 0.19$). Age seemed to be associated with slightly significant differences when testing respondents younger than 26 years old compared to those older – but only for uneasiness ($\chi^2(2) = 8.67, p < 0.01$ and for TD ($\chi^2(2) = 5.59, p = 0.018$); while not for PoT ($\chi^2(2) = 0.01, p = 0.91$), and confusion ($\chi^2(2) = 0.03, p = 0.85$). A post-hoc Mann-Whitney U confirmed lessened uneasiness ($p < 0.01, S = 0.13$) and greater temporal distances ($p < 0.01, S = 0.13$) for people 25 and younger compared to older respondents, but the lack of elderly people in our

sample prevent us from identifying possible effects in this age group. Similarly, no significant differences appeared based on navigational expertise, but $\approx 98\%$ of our respondents take the metro system at least several times a week, which prevent us from identifying effects associated with navigational expertise. All in all, across the three sample-to-population imbalances we stressed in the previous section, age seemed an issue in terms of uneasiness and perceived distances, and education in terms of confusion.

Some additional tests appear noteworthy across the three factors resulting from factor analysis and the confusion variable, and which we report from most important to least important:

- **Disruption severity.** Complete interruption of traffic was significantly different from slowed-down traffic in terms of confusion ($\chi^2(2) = 25.85, p < 0.001$), TD ($\chi^2(2) = 5.68, p = 0.017$), and uneasiness ($\chi^2(2) = 9.65, p < 0.01$), but not PoT ($\chi^2(2) = 1.34, p = 0.25$). Post-hoc Mann-Whitney U tests confirmed increased confusion ($p < 0.001, S = 0.25$), increased uneasiness ($p < 0.001, S = 0.12$) and longer perceived temporal distances ($p < 0.01, S = 0.09$) during total interruption compared to slowed-down traffic. A narrower test also found no significant differences for PoT ($\chi^2(2) = 0.02, p = 0.90$) and TD ($\chi^2(2) = 0.66, p = 0.42$) between a slow-moving train and a stopped train.
- **Traveller's behaviour.** Waiting for the disruption to end or reorienting oneself didn't initially lead to significant differences in PoT ($\chi^2(2) = 2.21, p = 0.14$) and confusion ($\chi^2(2) = 3.12, p = 0.08$) when looking at all respondents, but the test statistics indicated that underlying effects might be present when narrowing the situation down. Travellers facing disruption in a train have a different agency compared to those who are located outside the network or in the hallways, as their initial state of captivity is greater. Similarly, total traffic interruption bears more weight to the traveller's reaction as one no longer is progressing on the itinerary. Indeed, travellers reorienting themselves when blocked in a train facing interrupted traffic ($n = 53$) vs those waiting for the disruption to end in the same situation ($n = 46$) showed significant differences in PoT ($\chi^2(2) = 4.56, p = 0.03$), but not for TD ($\chi^2(2) = 0.28, p = 0.6$), uneasiness ($\chi^2(2) = 0.78, p = 0.38$) or confusion ($\chi^2(2) = 0.07, p = 0.8$). A Post-hoc Mann-Whitney U test confirmed a substantially faster passage of time ($p = 0.016, S = 0.18$) for travellers reorienting themselves.
- **Reorientation directions.** Reorienting oneself on one's initiative versus because the transport operator suggested finding an alternative path led to a significant difference for TD ($\chi^2(2) = 10.07, p < 0.01$) while being not quite significant for uneasiness ($\chi^2(2) = 2.52, p = 0.11$) and PoT ($\chi^2(2) = 1.48, p = 0.22$) and not significant at all for confusion ($\chi^2(2) = 0.05, p = 0.82$). Post-hoc Mann-Whitney U tests confirmed shortened perceived distances ($p < 0.001, S = 0.21$) for disrupted travellers being advised during reorientation.
- **Gender.** Gendered differences were very significant for PoT ($\chi^2(2) = 13.71, p < 0.001$) and uneasiness ($\chi^2(2) = 6.76, p < 0.01$) but barely above threshold for TD ($\chi^2(2) = 3.57, p = 0.059$), and not significant at all for confusion ($\chi^2(2) = 0.18, p = 0.67$). A post-hoc Mann-Whitney U test confirmed a slower passage of time ($p < 0.001, S = 0.18$) and greater uneasiness ($p < 0.01, S = 0.11$) for women compared to men.

- **Commuting to work.** Going to work compared to other reasons underlying the disrupted trips resulted in only a significantly different degree of uneasiness ($\chi^2(2) = 8.61$, $p < 0.01$), which a post-hoc Mann-Whitney U confirmed to be greater ($p < 0.01$, $S = 0.13$). In comparison, going to work didn't amount to significant differences for PoT ($\chi^2(2) = 0.02$, $p = 0.88$), TD ($\chi^2(2) = 0.50$, $p = 0.47$), and confusion ($\chi^2(2) = 1.29$, $p = 0.26$).
- **Metro vs. RER.** Experiencing the disruption on a metro vs an RER line resulted in a slightly significant difference for TD ($\chi^2(2) = 4.08$, $p = 0.04$) and uneasiness ($\chi^2(2) = 4.05$, $p = 0.04$), but not quite for PoT ($\chi^2(2) = 3.14$, $p = 0.08$), while the difference in confusion was completely insignificant ($\chi^2(2) = 0.55$, $p = 0.46$). A post-hoc Mann-Whitney U confirmed slightly longer perceived distances ($p = 0.02$, $S = 0.08$) and greater uneasiness ($P = 0.02$, $S = 0.09$) during disruptions on an RER line.

As a way of exploring the influence of conflicted time feelings on disorientation, we calculated the % of respondents that agree to experience “at times” during disruptions, both slower and faster passage of time, and both shorter and longer perceived temporal distances to destination. As it happens, only 5.3% conflicted PoT (bootstrap CI: 3.3%-7.4%) and 4.6% conflicted TD (bootstrap CI: 2.9%-6.6%) respondents were present in our study. Combining these two conditions, 9.0% of our respondents (bootstrap CI: 6.36% - 11.84%) experienced at least a form of conflicted time feelings. Interestingly, however, memory delay had a very significant impact on the occurrence of conflicted responses. While 2.1% PoT (bootstrap CI: 0-9.7%) and 1.0% TD (bootstrap CI: 0-6.9%) respondents who completed the survey on the same day as the disturbance after it had occurred reported conflicted feelings, 16.7% PoT (bootstrap CI: 8.3-26.7%) and 11.7% TD (bootstrap CI: 5.0-20.0%) reported conflicted feelings when recalling a disturbance more than 2 weeks after it had occurred. Indeed, the difference in the frequency of conflicted time feelings between completing the survey on the same day, but after the disrupted journey had ended, and more than two weeks after it happened, was very significantly different for both PoT (Fisher's exact test, $p < 0.01$, odds ratio = 9.4) and TD (Fisher's exact test, $p < 0.01$, odds ratio = 12.55). Conflicted time feelings thus mainly appear over time, with increased recollection delay. No significant differences were found for both uneasiness ($\chi^2(2) = 0.53$, $p = 0.42$) and confusion ($\chi^2(2) < 0.01$, $p = 0.94$) between respondents having experienced at least a form of conflicting time feelings and those that consistently reported time distortions in only one direction at once when filling the questionnaire 2 weeks after the disruption occurred.

Table 1 shows a multivariate OLS regression analysis with PoT and TD as independent variables and confusion as the dependent variable. F-test significantly departs from 0, which means that PoT and TD together explain a significant subset of the variation in confusion. The low value of R^2 indicates that only around 4.2% of the variation in confusion is explained by the model. PoT and TD do not seem to be good predictors of confusion, as the adjusted R^2 is barely 3.8%.

**Multivariate regression analysis (OLS):
Confusion~+TD+POT**

R ²	0.042	F-test:	8.968
Adjusted R ²	0.038	Prob > F:	0.00015
Independent variable	Coeff	T-statistics	p-value
INTERCEPT	4.6564	14.231	0
TD	-0.3841	-2.933	0.04
POT	-0.2476	-1.995	0.047

Table 1: estimated results by OLS multivariate regression analysis.

Discussion

Public transport users experience disorientation during traffic disruptions. However, no previous research has investigated their experience at the very moment of disruption. We demonstrated the relevance of a new real-time survey distribution method based on travellers interacting with traffic disruption announcements on Twitter to recruit participants in the Paris area from August to October 2022.

The results show that during disruptions, travellers mostly report a combined slowing of the passage of time and a feeling of being temporally further away from their destination (time dilation). To the best of our knowledge, our study was the first to compare passage of time and temporal distance judgements of an acute momentary episodic crisis between respondents still undergoing the event and respondents filling out a questionnaire afterwards. As other researchers have stressed (e.g. Droit-Volet et al., 2021), the distinction between present passage of time (also known as prospective PoT) and past passage of time (also known as retrospective PoT) shouldn't be overlooked, as these phenomena involve partly different cognitive processes. Comparing our travellers partaking in the study while still navigating the transit network to those for whom the trip is over, we report a noteworthy bias whereby a public transport disruption is remembered as faster and the distance from the destination as shorter compared to the actual experience. This result is consistent with previous works suggesting that the fewer autobiographical memories activated during a passage of time judgement, the faster time seemed to have passed (Kosak, Kuhbandner, and Hilbert, 2019): allegedly, the number of memories activated about the disruption diminishes with the passing days, which would explain the perceived acceleration of the passage of time in the episodic memory of the disruption. Time slows down during traffic disruptions, yet the passage of time in the episodic memory accelerates over the passing days in the wake of the disruption, confirming our two first hypotheses. These confirmations align with Flaherty's model of the passage of time (2018) while generalising the results to temporal distance judgements, which are known to be correlated with passage of time judgements (Ogden and Piovesan, 2022). Both uneasiness and confusion were also substantially higher for the respondents filling out the survey during the disruption. These results suggest that after disruptions, episodic compression unfolds through the passing days across disorientation features.

As time dilates during traffic disruptions in a similar way compared to other problematic circumstances, does that mean that traffic disruptions share the same disorientation structure as other crises? Another hypothesis we formulated was tied to a phenomenon known as *vertigo* (Knight, 2022), and was motivated by the numerous studies about both PoT and TD reporting bi-modal distortions during prolonged crises, e.g. the Covid-19 pandemic (Ogden, 2020; Kosak et al., 2022; [authors]). Our questionnaire design allowed people to express conflicted time feelings, e.g. that *at times*, time passes faster during the disruption, and *at times*, it passes slower. It turns out that conflicted time feelings significantly appeared over time, with increased recollection delay (from $\approx 2.1\%$ PoT and $\approx 1.0\%$ TD responses on the same day of the disruption, after it was over, to $\approx 16.7\%$ PoT and $\approx 11.7\%$ TD responses if the disruption is more than two weeks old). No significant differences appeared in terms of both confusion and uneasiness between respondents expressing conflicted time feelings and those who reported time distortions in single directions. We then need to reject our third hypothesis: conflicted time feelings do not exacerbate disorientation *within the context of the remembered episode*, as they marginally appear when the episode is first experienced. This also explains why conflicted time feelings not associated with confusion or uneasiness, which are about the experience of the disruption: by being a feature of the memory encoding and retrieval processes, vertigo is disjoint from the experience itself. It appears then that not all sorts of temporal confusion are equal, even though they can be laid upon each other: recalling one's past disorientation during a traffic disruption can be intertwined with vertigo at the level of episodic memory. One's past temporal perspective can be confusing, irrespective of the disorientation being introspected upon.

In fact, time dilation in general isn't itself a strong predictor of the overall confusion during traffic disruptions, despite a significant association, and as seen with the very low R^2 in multivariate regression analysis with PoT and TD as independent variables and confusion as the dependent variable. This seems odd, as confusion (or perplexity) is a central feature of disorientation (Fernández Velasco, 2022), and as both PoT and TD were strongly associated with temporal disorientation during the Covid-19 pandemic (Chaumon et al., 2022; van Wassenhove, 2022; [authors]). Recall that we just found two strong pieces of evidence that passage of time and temporal distance judgements within the episodic memory get distorted over time, both in terms of quantity (more compressed over time), and quality (more diverse over time). The nature of the types of disorientation experienced during a pandemic and a traffic disruption differ: while pandemic disorientation is existential (Ratcliffe, 2021) and can be sustained across months and years (Ogden, 2021; Droit-Volet et al., 2021), traffic disruption disorientations mostly do not persist once the trip is over, which makes them local episodes of disorientation (Stegmaier, 2019). Our results then suggest that during local disorientation such as that which is experienced in service disruptions, other factors may prevail in best explaining the uncanniness of the experience; in turn, vertigo seems to be a feature more characteristic of the temporality of chronic crises in which one never ceases to be disoriented and faces a whirling succession of puzzling temporal feelings when trying to cope with confusing past events (Knight, 2022).

Situational variables had the strongest effects on the disruption experience. Expectedly, totally interrupted traffic led to much higher levels of confusion, uneasiness, and the destination

feeling farther away compared to slowed-down traffic. In contrast, no significant difference was present for PoT depending on the severity of the disruption. An additional test confirmed that there were no significant differences in the passage of time between the passengers in a slow-moving train and those in a stopped train, which suggests that the slow passage of time is tied to the unexpectedness of the disruption rather than to the speed of the vehicle. Passenger information about whether travellers should wait or reorient themselves reduced the perceived temporal distance to the arrival but didn't make time pass significantly faster. Very interestingly, travellers choosing to change their path when boarded on a train stopped at a platform experienced a much faster passage of time but not a shorter temporal distance to their destination, compared to those staying put and waiting for the disruption to end.

These three results come together in confirming our fourth and final hypothesis: that travellers exercise their agency during disruptions in part to make time pass faster. The equal propensity for time to slow down during slowed-down traffic and interrupted traffic corresponds to an equal signal that something is off, even though the difference in the accompanying confusion is important. Strikingly, the decision of travellers to change their path when boarded on a stopped train can't be explained by the perspective of a shorter alternative trip, as this perspective doesn't appear so to them. The acceleration of the passage of time they experience seems to indicate that they choose to change their itinerary because they long for synchronicity and prefer being on the move with their fate in their hands, rather than passively accepting the problematic circumstances. This is even more striking as these travellers also do not experience significant differences in terms of both uneasiness (i.e. discomfort, pressure, stress, anxiety) and confusion, which then can't explain their behaviour. This also aligns with the fact that those who received orientation advice didn't experience a faster passage of time: passenger information reduces the perceived temporal distance to a destination by guiding travellers, but the new trip remains dense in terms of experiences, feelings, and micro-decisions. All in all, our analysis supports Flaherty's suggestion (2018) and Dyer's specific claims about subway riding (2021) that temporal agency is overlooked: people not only experience time slowing down when facing problematic circumstances, they often act to affect their temporal experience. We provide strong evidence of the matter in the particular case of subway riding.

Some of our results warrant further investigations. Women don't differ from men in their experience of confusion, but they report a substantially slower passage of time and increased uneasiness, i.e. greater time pressure and anxiety. Subway riding is a particularly gendered experience in terms of perceived safety (Chowdhury and van Wee, 2020). It might be that during disruptions, women feel less secure and more alert than men, as they tend to be more subject to aggressive behaviour in the metro. It might also be that they have gender-related more time-pressured chores (e.g. picking up children after school), or that they bear more social prejudice if they were to arrive late at work, which would explain their greater uneasiness.

On another related note, commuting to work also leads to increased uneasiness, while on the other hand taking an RER line (i.e. a suburban version of metros) leads to a greater perceived temporal distance to the destination and greater uneasiness. As RER lines span across the greater Paris area, are more used for commuting to work compared to metro lines and offer

fewer alternate routes (unlike metro lines), greater perceived distances and increased uneasiness are not surprising. As commuting to work happens during rush hour, increased uneasiness can be explained by both the social pressure of being on time at work and the discomfort associated with network saturation, which has been previously stressed as a key factor for mass transit systems (Fisch, 2018). These two results indicate that disruptions are more badly experienced during the morning commute and on suburban lines offering fewer alternatives. Additional anthropological analyses are needed to unravel the gendered aspect of subway riding, as well as the intricacies of the uneasiness associated with the various social pressures behind the temporal ones in mass transit systems.

Limitations

We used non-parametric tests due to skewed distributions shown in Figure 1 towards extreme ratings. Extreme ratings may be due to more participation from exasperated travellers, when proposed. As invitation links were anonymous, these could be shared or retweeted among groups of travellers weary of experiencing disruptions daily, which may induce a sampling bias, especially for travellers agreeing to testify about past disruptions. It is important to note that these are not the same respondents we test at each time point to document effects associated with recollection delay. Future studies could try to only recruit in-the-moment respondents with a longitudinal design to better assess the effects of recollection delay. An additional question regarding one's involvement in public transport operations, policy, or public debate should also be added in future studies. Finally, the use of attention checks in the questionnaire could also be experimented upon, as previous works have suggested this could increase data quality in online surveying (Shamon and Berning, 2020), preventing both careless responding as well as nudging a more important cognitive effort in answering key introspective items.

It also remains unclear to what extent we depict a complete picture of the disorientation ensuing from disruptions. Neither time dilation nor the uneasiness of the situation (which was captured by degrees of stress, anxiety, discomfort, helplessness, and pressure to get to the destination) seems to clearly cut through what counts as disorientation and what doesn't. In addition, we conceptually mentioned that confusion was only a central feature of disorientation but was not sufficient on its own. In our study, confusion was a single variable and didn't form a disorientation component in factor analysis. We were cautious in limiting the time needed to fulfil the questionnaire to around 5 minutes to ensure people navigating the network would find enough time to fill it completely. Still, more phenomenological analysis needs to be conducted in order to better capture other unprobed aspects of disorientation during service disruptions, e.g., by means of Likert-scale questions focused on narrow aspects of the experience rather than on broad emotional features.

Conclusion

Public transport users experience time dilation during disruptions, with time slowing down and the perceived temporal distance to destination increasing. However, over time, people

remember their disrupted trip as passing faster and the temporal distance to the destination as shorter compared to what is reported in real-time during disruptions. On top of that, the proportion of our participants expressing conflicted feelings, e.g., time passing, at times, slower and faster during the disruption, increased with recollection delay. This suggests that the content of disorienting events is both compressed and twisted over time in memory. In episodic or local forms of disorientation, like traffic disruptions, time dilation seems to be a poor predictor of confusion. Coincidentally, we even find strong evidence that travellers change their itinerary during severe disruptions to make time pass faster, as this decision doesn't make the remainder of the trip feel shorter, less confusing, or less uneasy to navigate. This last finding is of particular interest to time researchers, as it provides a clear example of the exercise of temporal agency during a crisis that slows down time to make it pass more quickly.

The mnemonic biases we document also highlight the need for timely data collection when researching subjective experience during crises. In this respect, our study also serves as a proof of concept for the real-time distribution of surveys via social media during unexpected problematic circumstances. We argue that such a distribution leads to improved precision, efficiency, and scalability, as well as better data quality, as automated online distribution reduces the inertia between the disruption and the probing of its experiential features.

Finally, in terms of transport policy, this study suggests that public transport operators should explicitly tell travellers whether they should wait or change their route in the event of traffic disruption, as this tamps down their experience of time dilation.

Data Availability: All relevant data (analysis notebook, raw data) can be accessed on this OSF archive: https://osf.io/dkwmz/?view_only=8928b5ebaadf489687e1ef2a06579457

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