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2020 feels slow, long, and far away: Time distortion due to the COVID-19 pandemic

Judit Castellà[1] | Taiji Ueno[2] | Richard J. Allen[3]

[1]Department of Basic, Developmental, and Educational Psychology, Autonomous University of Barcelona, Bellaterra, Catalonia

[2]Division of Psychology and Communication, School of Arts and Sciences, Tokyo Woman's Christian University, Tokyo, Japan

[3]School of Psychology, University of Leeds, Leeds, UK

Correspondence
Judit Castellà, Department of Basic, Developmental, and Educational Psychology. Faculty of Psychology. Edifici B, Campus UAB. 08193, Bellaterra, Barcelona, Catalonia.
Email: judit.castella@uab.cat

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Abstract

The COVID pandemic has been an unforeseen situation in which uncertainty, social distance, loss of stability, and significant changes have proven to have detrimental effects on people's well-being and on mental health. The aim of the present study is to determine changes in subjective time speed, duration, and time distance, and to consider the factors that may have contributed to this subjective distortion. A questionnaire was designed to explore time perception along with autobiographical recollection, mental and physical activity, and mood before, during, and after the pandemic. Analysis revealed that the pandemic period differed from before and after on every scale; subjects reported relatively lower values on autobiographical memory for the pandemic period; felt this time period to be further away, slower, and longer; were less active; and had a more negative mood. A structural equation model revealed that mood was the main predictor of subjective time distortion.

KEYWORDS
COVID, memory, pandemic, time perception

1 | INTRODUCTION

The coronavirus pandemic has been an unforeseen situation in which social distance, uncertainty, loss of freedom and stability, and significant changes in routines have proven to have detrimental effects on people's well-being (Brooks et al., 2020; Castellà & Muro, 2022; Muro et al., 2021) and mental health (Lai et al., 2020; Liu et al., 2020; Xiang et al., 2020; Zhu et al., 2020). Regarding subjective feelings and personal experiences of this unusual period, there is a popular, common complaint regarding subjective changes in time speed or difficulties to judge when certain events took place during the course of the pandemic. But has our time perception actually changed during this period? And if so, what are the factors that have contributed to this subjective distortion? These are the questions that motivated the present study and with this aim, a questionnaire was designed to explore time perception along with autobiographical recollection, mental and physical activity, and mood before, during, and after the pandemic. Several recent studies have addressed the impact of the lockdowns on time perception (Brenlla et al., 2022; Droit-Volet et al., 2020, 2021; Kosak et al., 2022; Mascioli et al., 2022; Ogden, 2020, 2021; Wessels et al., 2022; Wittmann, 2020), and on memory or other cognitive abilities (Baliyan et al., 2021), but to our knowledge none has combined time and memory distortions, nor has compared several temporal moments in a comprehensive way (before, during, and after).

There are several ways to measure time perception. People can estimate how fast or slow time seems to pass (passage of time judgements), judge subjectively how long events or stimuli last (duration judgments) and estimate how far away or close in time an event is (temporal distance). Passage of time judgments appears to be closely related to the content of the event and the emotions that are elicited. Hedonic properties such as excitement and pleasantness are usually

associated with faster judgments (Wearden et al., 2014) while negative affect and fear correlates with slow judgements (Campbell & Bryant, 2007). Therefore, emotions play a crucial role in time distortion and emotional experience is also likely to have been affected during the pandemic period. According to a recent review of the psychological impact of disease-related quarantines (Brooks et al., 2020), the vast majority of people reported increased negative feelings such as fear, anger, nervousness, sadness, and guilt during the lockdown period. Other stressors involved were fear of infection, frustration, and boredom due to loss of routine and reduced social contact. In this sense, it is important to assess mood when studying time perception distortions.

On the other hand, all these time measures can be taken prospectively (i.e., when the participant knows in advance that a temporal decision will have to be made) or retrospectively (after the target interval has already passed and participants are not aware that they will be asked to judge time). Therefore, judgments under a prospective paradigm are directly related to the amount of attention drawn to the temporal information of the event (Zakay & Block, 1997) whereas retrospective measures are based on inferences and information retrieved from memory (Block & Gruber, 2014; Wearden et al., 2014), and due to their different nature and underlying mechanisms, both types of paradigms might lead to different outcomes. When using a retrospective paradigm, tasks usually involve longer intervals and are more similar to real life situations, and this is the approach that will be used in the present study. Some previous studies on time experience during COVID took time measures while the pandemic was ongoing and others took them months later, and although they all seem to be retrospective time measures because they refer to a past episode, studies that took several daily/weekly measures could have been tackling prospective mechanisms as participants were aware that they would be asked about time experience.

This is for example the case of the study conducted by Ogden (2020) that sought to determine passage of time during the COVID-19 lockdown period by asking about subjective time speed at daily and weekly points, along with negative mood (depression, anxiety, and stress), social satisfaction and physical activity. It was found that subjective passage of time was indeed distorted but in different directions across individuals; time was reported as passing quickly or slowly with an approximately equal split across participants. Regarding predictive factors, affect had a consistent effect in the form highlighted before (i.e., positive affect—faster judgements, negative affect—slower judgements) and reduced social satisfaction was associated with slowing of the passage of time.

In a similar vein, Droit-Volet et al. (2020) conducted a study on passage of time during the lockdown period and showed a slowing down during the confinement (relative to a 'before' comparison), which was mainly explained by boredom and negative mood (sadness). These results were replicated in a longitudinal study by Droit-Volet et al. (2021), which also showed a persistence of the slow-biased time passage a year after the first lockdown, so no return to the 'before' period was found in terms of time experience. Mascioli et al. (2022) also analyzed time speed along with several variables such as emotions and daily routines 2 months after the beginning of social distancing and extended the measures for 14 weeks. However, instead of using a single time speed judgement, they opted to measure 'time awareness', a more comprehensive yet indirect measure, that included time expansion and time pressure. In line with previously mentioned studies, they found a slowing down experience during the first weeks that was not as strong as weeks went by. Emotions and loneliness were the main drivers of this. Therefore, a slowing down of perceived time seems to be the most frequent finding in the literature. However, Brenlla et al. (2022) used the same questionnaire as Ogden (2020) for their Argentinian sample 5.5 months after the first lockdown when people were still in isolation and in this case, the experience of time passing more quickly than before the pandemic was more commonly reported than time passing more slowly. It has to be noted, though, that this and Odgen's study used a daily and weekly time speed judgement, which might involve prospective time mechanisms to a greater extent, and which might differ from a longer epoch's retrospective assessment that usually yields slower judgments (Wearden et al., 2014).

As mentioned before, time perception can also be assessed through duration estimation measures (long/short), that may not be directly related to passage of time (slow/quick) judgements: Durations might be estimated as identical but lead to significant differences in passage of time judgments. Conversely, a feeling that time has 'dragged' or 'flown' can be associated with either longer or shorter duration estimates. (Castellà et al., 2017; Wearden et al., 2014). Kosak et al. (2022) included both measures in their survey conducted around a year after the start of the pandemic, and compared temporal judgements of that year with their own research group's prior results regarding the previous year to determine whether there was a specific time distortion phenomenon associated with the pandemic, using a retrospective paradigm. Affective states were also assessed. To evaluate duration estimation participants were asked whether 'the last 14 previous months had lasted subjectively like a typical 14-month period'. Their participants reported a slowing down in time speed during the previous year compared to before the pandemic but the experienced duration since the start of the pandemic was rated as relatively shorter than usual (56% of the participants). The majority of those who rated the interval as relatively short also judged it to pass quicker. The opposite pattern was reported by Ogden (2021) who found that 54% of the participants rated the previous 8 months (time since the beginning of the pandemic) as longer, while the days and the weeks seemed to pass more quickly than usual. Despite their differences, in both studies, negative affective patterns (boredom, depression), and reduced satisfaction with social interaction were found to be significant predictors of temporal distortion toward a slowing down and a longer duration, while perceived increase in routine correlated with a shorter duration.

A crucial factor that must be considered when exploring duration estimation is its connection with memory. Theoretical models such as the storage-size model proposed by Ornstein (1969) suggest that perceived duration depends on the amount of space required to encode and store events in memory. So, a greater complexity or a higher

number of stimuli require more memory space, and the subjective duration of an interval increases. On the other hand, authors such as Fraisse (1967) and Poynter (1989) developed the change-segmentation model, in which the number of perceived changes in terms of more distinct segmentations is assumed to be responsible for an expansion in the remembered duration. According to Poynter (1989), a duration judgement is based on the ability to sequence the events that occur within an interval relative to the whole duration. In fact, event segmentation is influential in memory formation and can help with retrieval much later (e.g., Flores et al., 2017). Therefore, the number of details stored in memory, the amount of changes that occur during the interval, and its complexity have a key role in retrospectively judging the duration of a given interval, and in this sense having fewer memorable events stored, less distinctive changes and a lack of structure/segmentation during the pandemic might impact on episodic memory as well as time experience, making people feel that its duration was shorter when looking back (Wittmann, 2020).

Currently, there is relatively little existing evidence regarding the effects of the COVID-19 pandemic on autobiographical memory (Brown, 2021; Castillo et al., 2022; Öner et al., 2023; Rouhani et al., 2023). The pandemic started abruptly and the quarantines changed people's lives drastically, creating an inflection point that might have had an effect on how well events prior, during, and after the pandemic are remembered and on how the events are temporally distributed. In this sense, Brown (2021) proposed a framework by which an increase in event memories at the outset and a decrease during subsequent lockdowns is hypothesised, and this has been recently confirmed by Rouhani et al. (2023). The variability and amount of events stored in memory during the different periods might impact time experience differently and this is why an autobiographical memory questionnaire was administered in the present study. Moreover, due to its links with this type of memory (Friedman, 2004; Ross & Wilson, 2002) distance judgements were also included in the present study. Such judgments are not as commonly used in the time perception literature as those concerning speed and duration, but they may be useful in providing further insight regarding the possible relationship with autobiographical memory.

Finally, mental and physical activity might also have contributed to temporal distortion. A lack of activity and boredom seem to be predictors of slower passage of time (Droit-Volet, 2020; Kosak et al., 2022; Wessels et al., 2022) while more routine activities point to an acceleration of subjective time (Kosak et al., 2022; Wittmann, 2020). However, Ogden (2020) found that reduced physical activity correlated with higher levels of negative mood, but it was unrelated to temporal judgements. As supplementary data, some broader questions were included at the end of the questionnaire.

Taken together, the present study aims at analyzing potential changes in retrospective time perception due to the pandemic. It explores this topic with a broader perspective because it includes the year before the pandemic's start, the period between the start and participants' subjective end point, and the period after the pandemic end point to present, while most of the research has been conducted focusing on the lockdown periods. It also includes three different time measures. We aim to explore self-reported changes in temporal experience over these time periods, along with changes in autobiographical memory, activity, and mood, and the possible relationships between these. According to previous research we expect to find: (a) a general distortion regarding time speed, duration, and distance, and differences across phases; (b) differences between phases in autobiographical memory scores, activity, and mood, (c) higher memory scores during the pandemic will be associated with longer perceived duration; (d) lower activity level will be associated with slower feeling of time speed; and (e) more negative mood (or less positive mood) will be associated with a slower feeling of time speed. Structural equation modelling will also be conducted to further explore the observed correlations. This will enable us to link the expected temporal distortion with potentially contributing factors such as autobiographical memory, physical and mental activity, and mood. In doing so, we expect to provide insight into the factors that predict temporal distortion to a greater degree.

2 | METHODS

2.1 | Participants

An initial sample of 291 participants accessed the URL of the online questionnaire. Only those participants who gave fully informed consent and answered all questions were included in the data analyses. In addition, as the vast majority of respondents were from either the United Kingdom or Catalonia, only participants who were living either in the United Kingdom or in Catalonia in the last 3 years were included in the sample. The final sample ($n = 168$, 137 females, 27 males, 4 other responses) ranged from 18 to 75 years old ($M = 29.37$, $SD = 14.86$). 107 participants were living in the United Kingdom during the last 3 years, 61 in Catalonia.

Participants were informed of the procedure before answering the questionnaire. All collected information was password protected to ensure the strictest confidentiality. To ensure anonymity, participants were not asked for any identifiable information, they were asked to enter a memorable word, used to access their data if they wished to withdraw from the study. The study was approved by the Leeds University Ethical Committee (Ethical Approval Number: PSYC-600. Approval Date: 4/10/2022).

2.2 | Materials

Three different temporal measures were taken. First, subjective time speed before, during, and after the pandemic was assessed in a 5-point scale ranging from 1 (very slowly) to 5 (very quickly). Second, the subjective length of the period before, during, and after the pandemic was assessed in a 5-point scale ranging from 1 (very short) to 5 (very long). A third measure, temporal distance, was added that assessed how far/close in time a given time point feels subjectively in a 5-point scale ranging from 1 (much further away in time than it

actually is) to 5 (much closer in time than it actually is). These time points were the beginning of the year before the pandemic, the time point when the pandemic started, and the time point when they thought the pandemic ended.

Next, memory was assessed by the brief autobiographical recollection test (ART; Berntsen et al., 2019). It consists of seven items which are assessed on a 7-point scale ranging from 1 (strongly disagree) to 7 (strongly agree), one for each aspect of interrelated aspects of recollecting autobiographical memories: reliving, vividness, visual imagery, scene, narrative coherence, life-story relevance, and rehearsal.

The following block of four questions assessed mental and physical activity, by asking participants to judge to what extent they were mentally/physically active, ranging from 1 (very active) to 5 (very inactive), and whether their level of activity was increased or decreased compared to normal, ranging from 1 (much more active than I normally am) to 5 (much less active than I normally am).

Mood was assessed with the short version of the positive and negative affect schedule (PANAS; Mackinnon et al., 1999) which consists of five positive adjectives and five negative adjectives and asks participants to rate them according to the extent to which each describes the way they have felt during a specified time, ranging from 1 (not at all) to 5 (extremely).

Finally, we included four general questions about subjective experiences, such as the feeling of having grown older, or whether they had felt changes in the way they experience time and memory functioning. A final optional open question was added to allow participants to type any comment they would like to add.

2.3 | Procedure

The questionnaire was administered online through Qualtrics XM (2020) software, following the snowball technique, and some of the participants were recruited in exchange for credit course. Data were collected from the beginning of November 2022 until the end of January 2023. The questionnaire consisted of three sections. Before each section, participants were reminded which temporal moment the questions referred to: 'before the pandemic' (specifying 1 year before the pandemic, not the whole life since birth), 'during the pandemic' (because people vary as to when they feel the pandemic ended, first participants were asked to choose their own, subjective time point regarding when they felt the pandemic ended. The alternatives were '2020 Winter', '2020 Spring', '2020 Summer', '2020 Autumn', '2021 Winter', '2021 Spring', '2021 Summer', '2021 Autumn', '2022 Winter', '2022 Spring', '2022 Summer', or 'Not yet' Then, the questions referred to 'during the pandemic' as the time period after it started and before their subjective end point), and 'after the pandemic' (referring to the time period after their subjective end point to present). Before each section, participants were instructed as follows: '*We will ask a series of questions about your memory, experience of time, and feelings (before/during/after) the pandemic. In the questions below, we will refer to this period as (before/during/after) pandemic and you will be asked to respond to each question*'.

In each section, there were four blocks: questions about time perception, an autobiographical recollection test, questions about activity (both physical and mental), and questions about their emotional state.

3 | RESULTS

3.1 | Data availability

All the data and the R codes are available online (OSF: DOI 10.17605/OSF.IO/E9P6R).

3.2 | Internal consistency and descriptive statistics

Table 1 shows the descriptive statistics of each item at each time period. Table 2 shows the internal consistency measure (i.e., Cronbach's alpha) of ART, activity, and PANAS scales, and their correlation coefficients are shown in Table 3. We used an *R* package, *psych* (Revelle, 2022) when computing Cronbach's alpha. The averages of the existing scales (i.e., brief ART and short-PANAS) were calculated so that a higher value in each scale indicated having richer autobiographical memory (ART), being more positive (PANAS positive) and being more negative (PANAS negative), respectively. Regarding the activity level scale, all the items were reversed and averaged so that a higher value indicated being more active. Since we did not assume that the three temporal measurements formed a single latent factor, we neither computed a single aggregated score nor Cronbach's alpha. Instead, the inter-item correlation coefficients were estimated and are shown in the three rightmost columns of Table 3. Whilst the speed score and duration scores were correlated during the pandemic ($r = -.544$), such a relationship was weak before and after the pandemic. Moreover, the correlation coefficients between the distance score and the other two were either non-significant or very weak. These patterns supported our decision to treat these variables as potentially related, yet different measures, rather than the items for a single coherent factor/scale.

3.3 | Mean differences across the three time periods

Figure 1 shows the means, individual plots, and the *SE* for each scale at each of the three time periods. A series of repeated measures 1-way ANOVA (before, during, vs. after the pandemic) revealed significant main effects of the time period factor on every scale: scale names = [ART, activity level, PANAS positive, PANAS negative], *Fs* [2, 334] = [47.191, 43.754, 87.602, 61.973], *MSEs* = [1.044, 0.667, 0.571, 0.592], all *ps* < .0001, η_p^2 = [.220, .207, .344, .270].

A series of multiple comparisons with Bonferroni correction revealed that the means during pandemic were significantly different from both the means before and after the pandemic: Specifically, the autobiographical memory recollection (Figure 1a) was significantly lower during pandemic than both before pandemic, t (167) = 6.552, p < .0001, and after

TABLE 1 Means and standard deviations in each item at each time period.

Items	Before pandemic		During pandemic		After pandemic	
	Mean	SD	Mean	SD	Mean	SD
Autobiographical recollection test (strongly disagree ~ strongly agree)						
(1) My memories of events have lots of details.	4.577	1.550	3.911	1.709	5.262	1.381
(2) My memories of events come to me as good stories or descriptions	5.048	1.198	3.768	1.638	5.250	1.330
(3) While remembering events, it is as if I am reliving them.	4.411	1.529	4.101	1.596	5.125	1.389
(4) I often think back to events in my mind and think or talk about them.	5.137	1.452	4.250	1.659	5.202	1.454
(5) In my memories of events, I remember where the actions, objects, and people are located in the events.	4.881	1.413	4.137	1.589	5.244	1.302
(6) While remembering events, I can see them in my mind.	5.351	1.359	4.690	1.597	5.405	1.368
(7) My memories of events are a central part of my life story.	5.095	1.497	4.524	1.695	5.298	1.495
Three temporal measures						
(1) [Distance] [The beginning of the year before the pandemic, The time point when the pandemic started, The time point when I think the pandemic ended] feels: (much further away ~ closer in time than it actually is)	1.744	1.083	2.137	1.290	2.649	1.219
(2) [Speed] [Before, During, After] the pandemic, time went/goes by: (very slowly ~ very quickly)	3.196	0.980	2.250	1.247	3.982	0.951
(3) [Duration] The time period [before, during, after] the pandemic feels: (very short ~ very long)	2.964	0.953	3.661	1.232	2.464	1.066
Activity level						
(1) I was mentally: (very inactive ~ very active)	4.220	0.729	3.119	1.193	3.988	0.797
(2) I was mentally: (much more inactive ~ active than I normally am)	3.274	0.772	2.464	0.978	3.357	0.898
(3) I was physically: (very inactive ~ very active)	3.577	1.108	2.952	1.303	3.512	1.132
(4) I was physically: (much more inactive ~ active than I normally am)	3.143	0.871	2.661	1.223	3.077	1.055
PANAS positive (very slightly or not at all ~ extremely)						
(1) Inspired	3.125	0.992	2.333	1.207	3.119	1.093
(2) Alert	3.048	1.093	2.792	1.276	2.899	1.059
(3) Excited	3.458	0.978	2.030	1.108	3.315	1.033
(4) Enthusiastic	3.530	0.991	2.024	1.089	3.268	1.091
(5) Determined	3.661	0.990	2.589	1.230	3.476	1.044
PANAS negative (very slightly or not at all ~ extremely)						
(1) Afraid	1.982	1.097	2.976	1.248	2.101	1.167
(2) Upset	2.315	1.062	3.107	1.262	2.381	1.162
(3) Nervous	2.601	1.095	3.250	1.256	2.750	1.188
(4) Scared	1.946	1.057	2.899	1.275	2.030	1.176
(5) Distressed	2.185	1.167	3.107	1.349	2.357	1.328

pandemic t (167) = 8.890, p < .0001. The activity level (Figure 1b) was significantly lower during pandemic than both before pandemic, t (167) = 8.580, p < .0001, and after pandemic t (167) = 7.391, p < .0001. The PANAS positive score (Figure 1c) was significantly lower during pandemic than both before pandemic, t (167) = 12.407, p < .0001, and after pandemic t (167) = 9.677, p < .0001. Finally, the PANAS negative score (Figure 1d) was significantly higher (i.e., more negative) during pandemic than both before pandemic, t (167) = 9.314, p < .0001, and after pandemic t (167) = 9.058, p < .0001. To summarize, for the time during the pandemic, participants had reduced autobiographical memory, were less active, and felt less positive and more negative, relative to the periods before or after the pandemic.

TABLE 2 Reliability measure (Cronbach's alpha) in each scale at each time period.

Time periods	ART	Activity level	PANAS positive	PANAS negative
Before pandemic	0.810	0.640	0.760	0.850
During pandemic	0.860	0.700	0.700	0.910
After pandemic	0.910	0.760	0.780	0.880

Abbreviation: ART, Autobiographical recollection test.

TABLE 3 Correlation matrix between each scale and three temporal measurements within each time period.

Time period	ART	Activity level	PANAS positive	PANAS negative	Distance	Speed	Duration
Before pandemic							
ART	1						
Activity level	0.038	1					
PANAS positive	0.220*	0.320*	1				
PANAS negative	0.011	−0.106	−0.103	1			
Distance	−0.012	0.105	−0.140†	0.076	1		
Speed	0.025	0.025	0.023	−0.055	0.087	1	
Duration	0.049	0.019	−0.007	−0.033	0.003	−0.197*	1
During pandemic							
ART	1						
Activity level	0.260*	1					
PANAS positive	0.444*	0.441*	1				
PANAS negative	−0.243*	−0.161*	−0.363*	1			
Distance	0.021	0.011	0.056	−0.174*	1		
Speed	−0.092	−0.037	0.088	−0.002	0.169*	1	
Duration	0.141 †	0.124	0.106	−0.073	−0.223*	−0.545*	1
After pandemic							
ART	1						
Activity level	0.228*	1					
PANAS positive	0.383*	0.527*	1				
PANAS negative	−0.100	−0.157*	−0.062	1			
Distance	0.082	0.058	−0.038	0.018	1		
Speed	0.082	−0.067	−0.197*	−0.001	−0.129 †	1	
Duration	0.200*	0.052	0.148 †	0.019	−0.063	−0.204*	1

Abbreviations: ART, Autobiographical recollection test; degree of freedom = 166.
*$p < 0.05$;
†$p < 0.10$.

We also examined whether the additional factor of geographical area (Catalonia or United Kingdom) modulated the mean differences. As a result, the area factor significantly interacted with the time period factor on the following dependent measures: (i) on ART, F (2, 332) = 5.292, MSE = 1.018, p = .005, η_p^2 = .030; (ii) on the activity level, F (2, 332) = 3.859, MSE = 0.656, p = .022, η_p^2 = .022; and (iii) on the PANAS positive score, F (2, 332) = 18.089, MSE = 0.518, p < .001, η_p^2 = .098. However, the source of all these interactions was the variable size of differences between before and after the pandemic in each geographical area. Since our focus was the comparison between during pandemic and before/after the pandemic, rather than the contrast between before and after the pandemic, these details are reported in supplementary materials (see OSF: https://osf.io/e9p6r/).

More importantly, we were interested in the effect of time periods on each of the three temporal measurements. A one-way MANOVA was conducted to test the effect of time periods (three levels) on the distance score, speed score, and duration score (Figure 2 and Table 1). The multivariate effect of time periods was significant, Pillai's Trace = 0.114, F (6, 994) = 10.048, p < .0001. This result suggests that the time periods had a significant multivariate effect on the dependent variables. A series of multiple comparisons with a Bonferroni procedure revealed that every paired-comparison

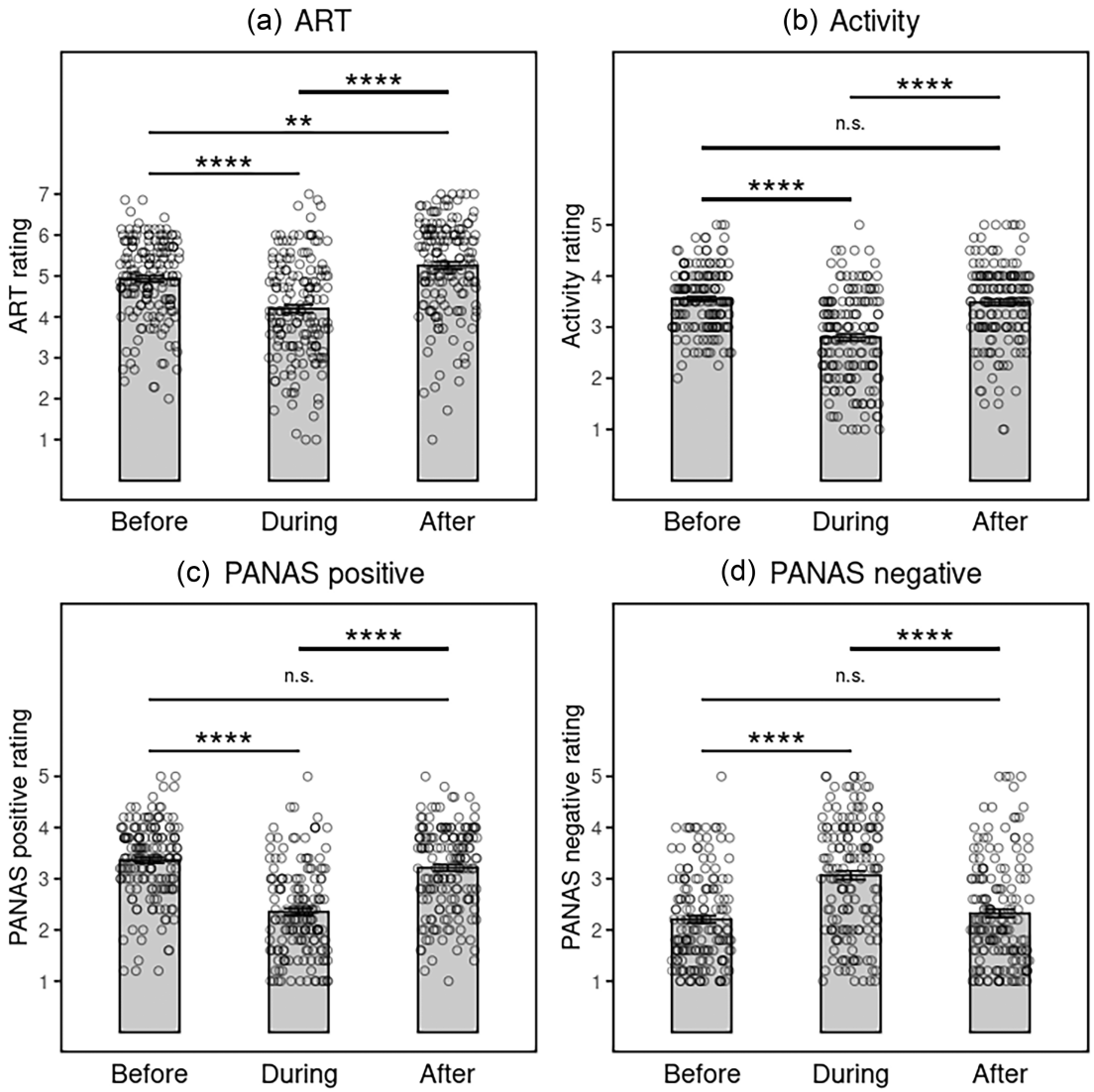

FIGURE 1 Mean scores (and individual plots and standard errors in y-axis error bars) in each scale as function of the time periods. (a) Autobiographical recollection test; (b) activity level; (c) PANAS positive score; (d) PANAS negative score.*p < .05, **p < .01, ***p < .001, ****p < .0001, ns = non-significant.

was statistically significant, ts (167) > 3.600, ps < .002 on every measurement. Namely, the distance score was higher (i.e., a feeling of being closer in time) after the pandemic, compared to during the pandemic, which in turn was higher than that before pandemic. Also, the speed score was higher after pandemic than before pandemic, which in turn was higher than during pandemic. Finally, the duration score was lower, which means 'feeling shorter', after pandemic than before pandemic, which in turn was lower than during pandemic.

Furthermore, it is worthwhile to interpret the outcome of the temporal measurements in the context of the respondents' perceived duration of the pandemic period. Specifically, if a given participant thought the pandemic lasted two years or longer, then it would be less surprising for them to feel the time period during the pandemic was longer than before/after the pandemic. We split the respondents into two groups in terms of whether they thought the pandemic finished within 1 year of the pandemic start point (i.e., up to winter 2021) or later (from winter 2021 onwards), and then conducted between-groups t-tests on the three temporal measurements during the pandemic. There was no significant group effect on any measurement, ts (166) < 1.27, ps > .203, *n.s.* Secondly, we conducted ANCOVA to test the effect of time periods on temporal measurements with the respondent-defined end timing as a covariate (the scores were converted into a continuous variable, e.g., 2020 Winter = > 1; 2020 Spring = > 2, etc.). The effect of time periods on each of three temporal measurements remained significant, Fs (2, 334) > 13.896, ps < .001, as did the multiple comparisons between before/after the pandemic and during the pandemic, ts (166) > 3.589, ps < .0013.

3.4 | Structural equation model on three temporal measurements

Next, we explored what factors predicted the distance, speed, and duration feeling in each time period with structural equation

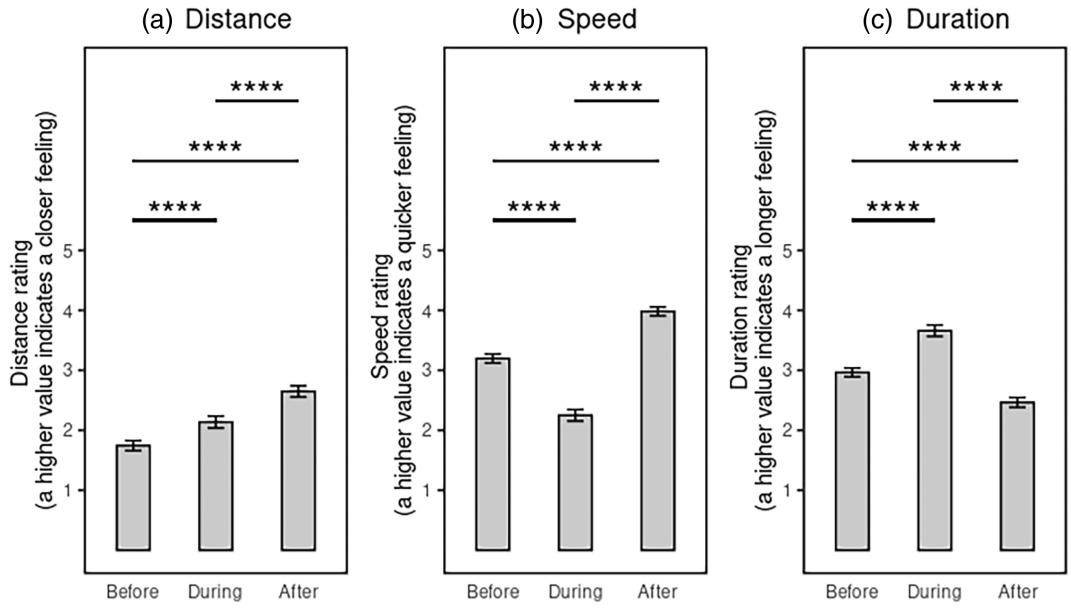

FIGURE 2 Mean scores (standard errors in y-axis error bars) in three temporal measurements as function of the time periods. (a) Distance score; (b) Speed score; (c) Duration score. *p < .05, **p < .01, ***p < .001, ****p < .0001, ns = non-significant.

modelling (SEM) using the *R* package '*lavaan*' (Rosseel, 2012). We first specified the full model as follows. The criterion variables were the distance, speed, and duration scores in each time period. The regressors included one observed variable ('age') and four latent factors 'ART', 'Activity level', 'PANAS positive', and 'PANAS negative', each of which were hypothesized to load the observed variables listed in Table 1. We also conducted a multi-group invariance test in order to show the equivalence between United Kingdom and Catalonia, and the outcomes are reported in the online materials (OSF).

Then, starting from the full model (i.e., Model ID 1 in each time period of Table 4), we examined various models by reducing the regressors (i.e., latent factors). The outcomes of the model comparisons are summarized in Table 4. The best-fit model (see Figure 3a–c and the Model ID 5 in each time period of Table 4) included only the PANAS positive factor and the PANAS negative factor without the age variable, the ART factor, and the activity level factor in each time period. Before the pandemic (Figure 3a), only the speed measurement was negatively ($\beta = -0.21$) predicted by the PANAS negative factor whereas the other regression coefficients from the PANAS factors to three temporal measurements were non-significant. During the pandemic (Figure 3b), both the PANAS positive factor and the PANAS negative factor predicted speed and duration significantly. Neither factor significantly predicted the distance measurement. After the pandemic (Figure 3c), neither the PANAS positive factor nor the PANAS negative factor significantly predicted any of the three temporal measurements. These patterns indicate that mood had a significant role in the feeling of distorted subjective time during the pandemic. All the factor loadings of the adopted model were significant and are shown in Figure 3a–c. Readers may be interested in whether the outcome was equivalent between the countries. Therefore, we conducted a multi-group measurement invariance test, and the outcomes are reported in the online materials (OSF). As a result, in each time period, the regression coefficients from the PANAS-positive and the PANAS-negative factors into the three temporal measurements were equivalent between these countries.

3.5 | Descriptive statistics of the general questions

Finally, Table 5 shows the descriptive statistics for the response in the general questions. As the negative skewness values indicated, the respondents agreed 'they feel they have grown older since the pandemic', and 'it is difficult for them to judge when events and episodes took place during the course of the pandemic'.

4 | DISCUSSION

The novelty of the present study was twofold. First, different temporal measures were taken regarding three broad periods (before, during, and after the pandemic). Second, measures of autobiographical memory, mood, and activity were included and combined to explore their contribution to time distortion. Results showed that there was indeed a time experience distortion that was especially marked during the pandemic, but mood, and not memory storage per se seem to play a significant role.

First, there was a clear difference between the period during the pandemic and the other time periods on every scale. For the period during the pandemic, subjects showed the lowest values on autobiographical memory; had a more distorted overall time experience (pointing to a bias towards a slower, longer, and further away period), were less active; and had a more negative mood.

The three-time measures showed consistent differences between periods: Subjective distance decreased with time, that is, the period

TABLE 4 Indices of fitting in the structural equation models on each of the data before, during, and after pandemic.

Timing	Model ID	Criterion variables	Explanatory variable/factors					Indices of fitting								
			Age	ART	Activity level	PANAS positive	PANAS negative	χ^2	df	CFI	TLI	log-likelihood	AIC	BIC	RMSEA	SRMR
Before pandemic	1	Distance, Speed, Duration	+	+	+	+	+	411.82	255	0.876	0.854	-5529.02	11196.05	11411.60	0.061	0.070
	2	Distance, Speed, Duration	-	+	+	+	+	380.15	234	0.884	0.863	-5530.38	11192.76	11398.94	0.061	0.069
	3	Distance, Speed, Duration	-	-	+	+	+	199.65	107	0.896	0.868	-3613.36	7318.73	7462.43	0.072	0.074
	4	Distance, Speed, Duration	-	+	-	+	+	271.74	158	0.900	0.879	-4731.67	9567.35	9729.80	0.065	0.067
	5	Distance, Speed, Duration	-	-	-	+	+	121.84	58	0.917	0.888	-2814.68	5695.36	5798.45	0.081	0.074
During pandemic	1	Distance, Speed, Duration	+	+	+	+	+	659.93	255	0.805	0.771	-5995.47	12113.02	12344.49	0.097	0.104
	2	Distance, Speed, Duration	-	+	+	+	+	586.43	234	0.826	0.795	-5996.47	12124.95	12331.13	0.095	0.089
	3	Distance, Speed, Duration	-	-	+	+	+	362.26	107	0.819	0.769	-4017.33	8126.66	8270.36	0.119	0.096
	4	Distance, Speed, Duration	-	+	-	+	+	295.17	158	0.916	0.899	-5034.49	10172.97	10335.42	0.072	0.074
	5	Distance, Speed, Duration	-	-	-	+	+	106.96	58	0.952	0.936	-3053.64	6173.28	6276.37	0.071	0.058
After pandemic	1	Distance, Speed, Duration	+	+	+	+	+	528.29	255	0.879	0.857	-5298.21	10734.42	10949.97	0.080	0.069
	2	Distance, Speed, Duration	-	+	+	+	+	489.35	234	0.886	0.865	-5299.16	10730.33	10936.51	0.081	0.067
	3	Distance, Speed, Duration	-	-	+	+	+	268.52	107	0.881	0.849	-3647.21	7386.42	7530.12	0.095	0.074
	4	Distance, Speed, Duration	-	+	-	+	+	316.51	158	0.915	0.897	-4518.36	9140.72	9303.17	0.077	0.061
	5	Distance, Speed, Duration	-	-	-	+	+	134.83	58	0.923	0.896	-2866.38	5798.76	5901.85	0.089	0.074

Notes: +/− indicates that each variable was included/excluded from the model. Abbreviations: ART, Autobiographical recollection test; AIC, Akaike information criterion; BIC, Bayesian information criterion; CFI, Comparative fit index; df, degree of freedoms; TLI, Tucker–Lewis index; RMSEA, Root-mean squared error of approximation; SRMR, Standardized root mean square residual.

before the pandemic felt much further away than calendar time, somewhat further away during the pandemic and a bit further away after the pandemic (although the latter mean value was close to the no-bias point). These findings are consistent with previous claims that distance estimates are less accurate the longer the interval and that accuracy in the distance estimation processes is quite poor for events that happened prior to the past few months (Friedman, 2004; Thompson et al. 1996). However, these authors also claim that distance impressions of events in the past are probably based on the vividness of events in memory and that events that are better dated (and remembered) are those that are positive, affectively extreme, infrequent, atypical, emotional, frequently rehearsed, and mentally involving. Moreover, the basic temporal distance bias (Ross & Wilson, 2002) refers to the fact that individuals tend to perceive positive autobiographical events as recent and negative autobiographical events as distant (irrespective of actual time distance). A trade-off between mood and vividness found in our participants might explain why the pandemic period, which obtained the lowest memory scores but the highest negative mood scores, was biased towards a somewhat distant feeling.

Regarding duration, the before period did not seem to be distorted in terms of perceived duration (a mean value around three indicates neither a long or short duration), while the period after the pandemic was judged as rather short (with mean values lower than three, indicating 'somewhat short' or 'very short' ratings). The reported values were high during the pandemic indicating a marked increase in subjective duration of this period. These results contradict those found by Kosak et al. (2022) but are more in line with Ogden (2021), who found that the majority of participants tended to rate the time since the beginning of the pandemic (8 months) as longer than a regular 8-month period. However, the results show the opposite of the outcome expected in terms of memory models of time perception, which would predict a shorter duration when looking back in periods that involve less distinctive changes and fewer memorable events (Wittmann, 2020). This will be further discussed later in this section.

Finally, speed was not particularly distorted in any direction before the pandemic (a mean value close to three indicates neither a slow nor quick passage of time speed) but a clear slowdown was reported during the pandemic. Subjective time speed then recovered after the pandemic, when in fact a marked acceleration was observed. Therefore, one of the clearest time distortions happening during the pandemic is a very significant slowdown of experienced speed, which is consistent with most of the previous studies on this topic (Droit-Volet et al., 2020, 2021; Kosak et al., 2022; Mascioli et al., 2022; Wessels et al., 2022), and is usually attributed to a lack of physical and mental activity (boredom) and negative mood, which we also found. In terms of recovery of this feeling to the values of the period before the pandemic, in which no particular distortion was observed, our sample showed a significant acceleration after the pandemic with a marked tendency towards a quicker passage of time, while Droit-Volet et al. (2021) found a persistence of the slowdown a year after the first lockdown. However, at the time of filling the questionnaires (almost 3 years after the first lockdown) participants of the

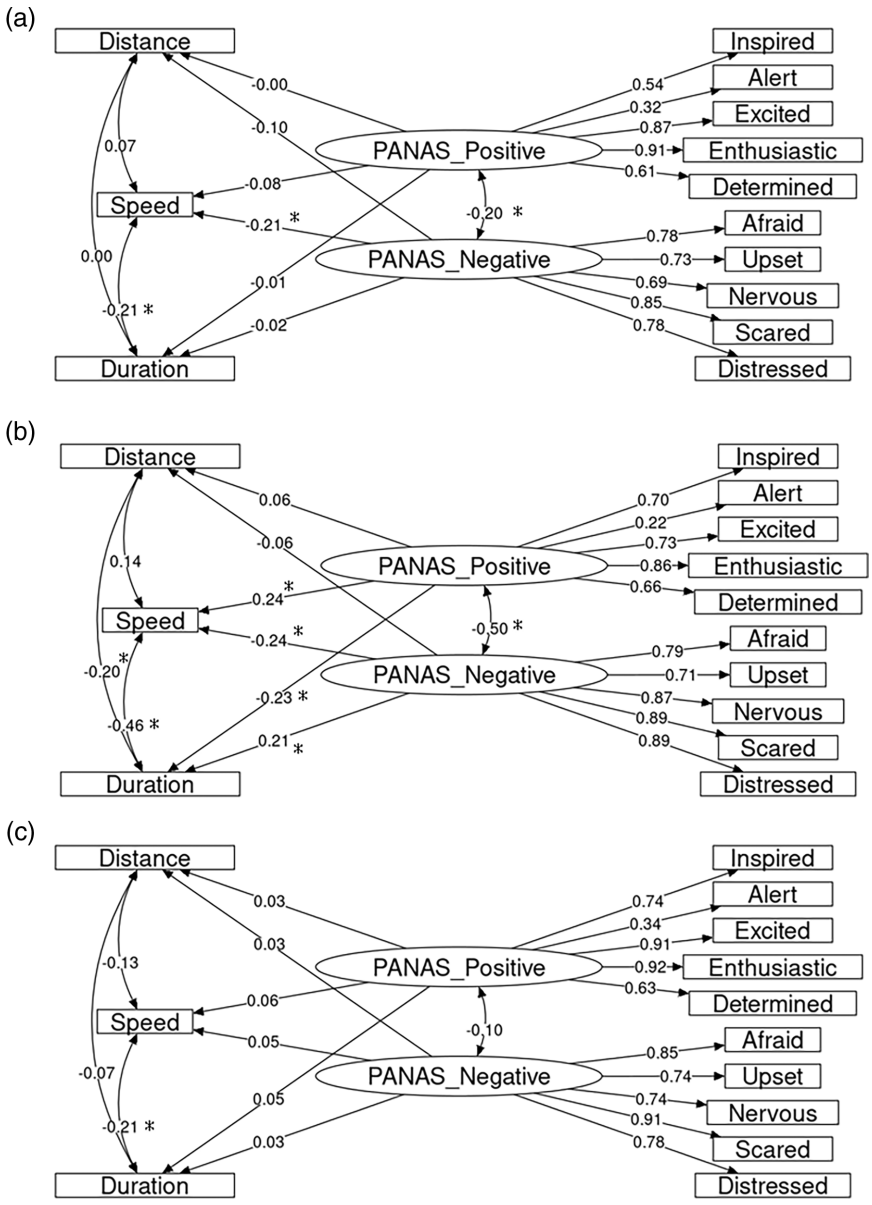

FIGURE 3 The adopted 2-factor model before the pandemic (a), during the pandemic (b), and after the pandemic (c). The arrows from the error terms are not displayed for the sake of conciseness. All the factor loadings were significant ($p < .05$). * indicates a statistical significance ($p < .05$) in the regression coefficients and in the covariances.

TABLE 5 Descriptive statistics for the general questions.

Item	Range	Mean	SD	Median	Kurtosis	Skewness
My memory works the same way as it did before the pandemic.	1:5	2.917	1.230	3	−1.051	0.160
I feel I have grown older since the pandemic.	1:5	4.012	1.243	4	0.758	−1.330
I feel that time passes the same way as it did before the pandemic.	1:5	2.655	1.238	2	−0.825	0.549
It is difficult for me to judge when events and episodes took place during the course of the pandemic.	1:5	3.833	1.177	4	0.052	−0.965

Note: All the questions were assessed in a 5–point scale ranging from 1 (strongly disagree) to 5 (strongly agree).

present study considered that the pandemic was already over. Time seemed to clearly stop during the pandemic and to fly afterwards, probably due to a restoration of daily routines and an increase in positive mood (Kosak et al., 2022). Wessels et al. (2022) also saw a progressive acceleration as levels of boredom decreased and the general emotional state improved in the months following the first lockdown. Therefore, internal states, and not memory content, seem to play a major role in the perceived speed of time passage.

Considering the relationship between measures, it can be seen that duration and speed judgements point in the same direction, that is, the subjective feeling of fast/slow passage of time correlates consistently with shorter/longer duration estimates, contrary to a dissociation that is sometimes reported (Castellà et al., 2017; Wearden et al., 2014). There was a correspondence between these two judgements during the pandemic period, as it felt very long and speed was judged as slow, and this was also the case (although in the opposite direction) both before and after the pandemic, when an acceleration in passage of time judgments corresponded with shorter durations. In terms of the relationship between duration and distance judgements, it is expected that a longer-perceived interval such as the pandemic would have its initial point further away in time than a shorter interval and thus be judged as more distant, which is consistent with our findings.

As for contributing factors, age, memory, and activity level did not predict time distortion in each time period but mood (both positive and negative) did particularly during the pandemic. In that period, positive and negative mood were good predictors of a distortion in speed and duration in the sense that faster and shorter time feelings were due to a positive mood whereas a negative mood was responsible for slower and longer duration feelings. Ogden (2020) found this same consistent effect in time speed, and most of the reviewed studies that found some kind of slowing down due to the pandemic highlighted the contribution of negative emotional state, negative affective patterns, loneliness, depression, or boredom to this phenomenon (Droit-Volet, 2020; Kosak et al., 2022; Mascioli et al., 2022; Ogden, 2021; Wessels et al., 2022). In our study, this was also the case, and it is important to note that PANAS explores emotional state (assesses negative adjectives include being afraid, upset, nervous, scared, and distressed), and so it seems clear that the negative emotions elicited by the pandemic caused a perceived slowing down in subjective time speed. Regarding duration, although not all the studies assessed it directly, Ogden (2021) and Kosak et al. (2022) also attributed longer duration judgments to high boredom, anger, sadness, depression, and low levels of contentment and low levels of satisfaction with social interaction. Along the same lines as our findings, these authors linked positive mood to a quicker passage of time and to shorter durations.

There have been attempts to explain the relationship between emotion and time perception but there are many variables to take into account, that is, the length of the to-be-judged time intervals (milliseconds or seconds, minutes, hours or longer periods), whether the participant is experiencing some kind of emotion (natural or elicited) or is in a neutral state but judging an emotional stimuli (such as human emotional expressions), and so forth (see Droit-Volet & Meck, 2007 for a review). One of the most common theories that have been put forward is the internal clock model, by which human timing depends on a pacemaker-accumulator (Treisman, 1963) and distortions of subjective time are interpreted as the result of changes in the speed of the pacemaker. For example, increased arousal accelerates the pacemaker and the subjective experience of time is lengthened, while non-temporal or emotional events that capture attention divert processing resources away from the timer, shortening the subjective interval (Zakay & Block, 1997). This model works for prospective timing paradigms in which the participants know in advance that the targeted interval will have to be estimated and might explain why Ogden (2021) and Brenlla et al. (2022) found that days and weeks were passing by more quickly than normal when assessed daily while the duration of the whole period seemed longer than usual.

For longer epochs such as in the latter case (duration of the whole period), and also those assessed in the present study, judgments are necessarily retrospective in nature. Such a retrospective paradigm is based on memory retrieval (Wearden et al., 2014), and helps inform understanding of episodic memory for the duration of emotional events (Droit-Volet & Gil, 2009). Regarding the role of episodic memory, the pandemic is unique in the sense that it is not only a single isolated event but it is long-lasting and has affected people's life trajectories, which can be understood under the *transition theory* (Brown, 2021). This theory predicts the generation of a bump in autobiographical memory at the onset, due to the initial instability, negative feelings, and an increase in the availability of event memories (spread of the virus, responses to limit the spread, politics and health systems, i.e., Öner et al., 2023), followed by a lockdown dip, due to the decrease in the creation of novel and distinct events in memory. This dip was put forward by Rouhani et al. (2023) to explain the remembered time compression during lockdowns found in their sample. The initial increase in event memory might serve as a clear boundary marker to delineate the start of the period, with the subsequent relative lack of event memories then having particular effects on time perception. However, this theory, and the more traditional theoretical models that link the quantity of information stored in memory in terms of details and/or distinctive changes with temporal judgements (Fraisse, 1967; Ornstein, 1969; Poynter, 1989; Wittmann, 2020) might predict shorter perceived durations during the pandemic due to a reduction of vividness and details, and an overall strong influence of memory as a contributing factor. Instead, we observed a longer subjective duration (as found by Ogden, 2021), and no influence of memory vividness, with mood instead showing a significant relationship.

The role of the elicited emotions during a to-be-remembered collective event on subjective time deserves special attention, as it seems to be the main predictor of our findings. As mentioned before, the impact of the global pandemic on autobiographical memory has just recently started being studied (Brown, 2021; Castillo et al., 2022; Öner et al., 2023; Rouhani et al., 2023). Collective event recall includes recall of details, which are prevalently and consistently recalled by individuals, but also memories of feelings during such an event, which in turn imply feelings generated upon recollection that might or might not be consistent. In any case, collective events such as the pandemic are often recalled with a negative valence and there is a tendency to overestimate the intensity of past negative feelings (Castillo et al., 2022). In our study, it is worth noting that participants' mood reports for the pandemic period are themselves based on a general memory of how they felt at that time. Thus, participants generally recalled time being distorted during the pandemic, and this was predicted by the extent to which they generally recalled feeling less positive and more negative. Taken together, results suggest that

remembered duration and passage of time judgments of long, negative, and distant intervals such as the pandemic are based more on an inference from the remembered mood (i.e., that time drags when we are having a bad time) than from event memory content or amount of information stored.

Finally, the supplementary questions at the end of the questionnaire showed a general agreement on a sense of having grown older since the pandemic, which could be due to the feeling of being stuck for months, as shown by the drop in mental and physical activity. The experience of a slow passage of time during a subjective long period might have also contributed, although this contrasts with the fact that participants reported not being aware of a change in the way their timing processes and memory work. They also tended to agree on having difficulties judging when events and episodes took place during the course of the pandemic. This may reflect a lack of contextual information in terms of landmarks or time references that could be used to infer when an event happened. Relatedly, temporal accuracy seems to be best when an event is well-remembered (Friedman, 2004), and our data shows that there was a clear drop in memory vividness during the pandemic. Thus, although the structural equation model highlighted mood rather than memory as a predictor of subjective time distortion, it remains possible that memory accessibility helps determine absolute and/or relative temporal accuracy.

In summary, the current study indicates that participants retrospectively report a clear time distortion for the period covering the COVID-19 pandemic, with a slowdown in subjective time speed and a longer reported duration during this period. We also find a significant role of mood in informing these subjective time judgments. This pattern is broadly consistent with those observed in related studies despite methodological differences. More research is needed in order to explore in-depth the underlying mechanism of this mood-induced bias. From a practical significance point of view, temporal distortion seems to be a common element in trauma-related experiences and in situations that induce negative states such as anxiety or depression (Castellà et al., 2017; Castellà & Muro, 2022; Holman et al., 2023; Holman & Grisham, 2020). Some studies have already focused on the factors that might predict time distortion when facing a traumatic and collective event such as the pandemic. For instance, Holman et al. (2023) found that temporal distortion was predicted by prior mental health, secondary stress, and trauma exposure among others. More understanding is needed on whether such distortions can be seen as an indicator of coping mechanisms or restoration of psychological wellbeing once the negative experience is over. Finally, studies on longer-term recall of the exceptional situation experienced during the COVID-19 pandemic would be informative to examine ongoing potential impacts on memory, time perception, and wellbeing.

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CONFLICT OF INTEREST STATEMENT

No potential conflict of interest was reported by the authors.

DATA AVAILABILITY STATEMENT

All the raw data, aggregated data, the outcomes of the additional analyses, and *R* codes (R core team, 2022) for this study are available online on Open Science Framework. OSF: DOI 10.17605/OSF.IO/E9P6R

ORCID

Judit Castellà https://orcid.org/0000-0002-6094-3516

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