



The perception and passage of time during public speaking

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ABSTRACT

Several studies have shown that anxious individuals experience a slower passage of time under threat conditioning. Anxiety-evoking situations have also been proposed to elevate arousal levels, which, in turn, alter one's time percept. However, the effect of social stressors on time perception remains significantly neglected. The current research aimed to investigate the impact of anxiety levels on time estimation and passage of time judgments during public speaking in healthy adults. Participants were recruited from a pool of students that had to give a presentation as part of a university course or their teaching duties. Following the presentation, they were asked to make retrospective time estimations on the duration of the latter, as well as to provide passage of time judgments. Self-reported questionnaires related to affective states, public speaking anxiety, and performance were also administered. Analysis showed that higher levels of public speaking anxiety predicted temporal overestimation and slower "feel" duration and passage of time. Moreover, the relationship between public speaking anxiety and passage of time was mediated by participants' mood states, which remained significant after -indirectly- controlling for fear of evaluation. Overall, our observations suggest that anxiety levels during public presentation significantly predict altered perception and experience of time. The latter can be explained by the speaker's mood status. Identifying the mechanisms that modulate timing under psychological stressors could complement our understanding regarding their impact on educational and social settings, as well as set the ground towards the development of early intervention and prevention strategies for those who suffer from stress-related disorders.

1. Introduction

For more than a half-century, timing research has accumulated evidence supporting that we are quite accurate on estimating durations in a millisecond-to several minutes range, complying to Weber's law (Haigh et al., 2021). However, despite this primitive sense of time – the so-called 'internal clock' –, human time perception is often biased (Droit-Volet & Gil, 2009). In everyday life, our experience of time fluctuates according to our emotional states. For instance, in pleasurable situations time seems to fly, while when one is distressed or bored, time seems to slow down (e.g., Droit-Volet, 2013; Droit-Volet et al., 2011). Thus, the emotional context of events plays an essential role in one's time percept.

Several studies have explored the emotionally induced temporal illusions, providing mixed findings (Lui et al., 2011). While some researchers support the temporal lengthening of emotions (Droit-Volet et al., 2004; Effron et al., 2006; Li & Yuen, 2015), others propose the opposite effect (Lui et al., 2011). The conflict becomes even more perplexing considering that different emotions have been found to exert different impact on time perception, as a function of valence and arousal. As

an example, Gil and Droit-Volet (2012) showed that joy, sadness, fear, and anger are linked with time dilation, whereas shame induced temporal contraction. The lengthening effect of anger and fear has been replicated in other studies as well, using emotional faces (Eberhardt et al., 2016; Tipples, 2008), sounds (Droit-Volet et al., 2010), and scenes (Angrilli et al., 1997; Fayolle et al., 2015; Grommet et al., 2011). Based on these findings, different emotions, varying in valence and arousal levels, stimulate dissociable approaching-avoidance mechanisms.

According to the prominent internal-clock model, temporal expansion related to emotions that induce salient avoidance motivation, could be attributed both to elevated arousal and increased attention allocation to the threatening environmental cues, impeding the pacemaker rate and enabling more mental events to be registered at the switch, respectively (Lejeune, 1998). Further support to this notion arises from clinical studies on social anxiety, where social situations – in the absence of exclusion threat- are accompanied by high arousal levels and negative attentional bias, due to fear of negative evaluation (Buckner et al., 2010). Specifically, Yoo and Lee (2015), explored the influence of arousal and valence on time processing in a sample of socially anxious individuals. Using, four types of facial expressions, they

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found that highly anxious participants exhibited greater temporal dilation during the presentation of high-arousing negative stimuli as compared to high-arousing positive expressions. Oppositely, in the low-anxiety group, time overestimation occurred by stimulus valence; namely, low-arousal positive expressions were judged to last longer in comparison to low-arousing negative expressions. These results underpin the role of arousal and biased attention allocation during socially anxiogenic states.

To date, only few laboratory studies have examined whether individuals would present differences in temporal processing, as a function of induced social stressors (van Hedger et al., 2017). Using a modified version of the Trier Social Stress Test (TSST; Kirschbaum et al., 1993), participants had to prepare and deliver a speech, on a pre-defined scenario, in front of a video camera. They were told that their speech was going to be evaluated from a panel of experts. Before and after the task, they were instructed to reproduce the duration of positive, negative, and neutral pictures, ranging from 400 to 4.150 ms. Results showed that social stressors dilate temporal intervals regardless of the to-be-timed stimulus. Though, Jusyte et al. (2015), using a bisection task, found that individuals with social anxiety disorder exhibited greater temporal overestimation of angry versus neutral faces, following a stress manipulation, while such an effect was not evident in the healthy controls. In short, given the prospective nature of the tasks and the short duration presentations, the temporal lengthening effect could not be merely attributed to internal states (e.g., emotional arousal), as attention-related factors could also account for it (Martinelli & Droit-Volet, 2022).

To the best of our knowledge, even though impromptu speech tasks and oral presentations are frequently used to study subtypes of social anxiety (i.e., public speaking anxiety; Blöte et al., 2009), their effect on time perception has not been investigated under ecological conditions. Perception of time in a range of several minutes, that speech tasks (e.g., public presentation) usually last, is more sensible to be regarded as a retrospective judgement. In retrospective temporal processing, timing information is reconstructed from episodic memory. Recent, yet few studies propose that duration and passage of time judgments utilize common retrospective memory processes (Droit-Volet et al., 2018; Martinelli & Droit-Volet, 2022). In this case, when attention is not allocated on timing the present, temporal units are not encoded and interval estimations are based on non-temporal information retrieved from long-term memory (e.g., difficulty of the task and affective state during the interval; Block, 1992; Block & Reed, 1978). Thus, one could speculate that psychosocial stressors, such as public presentation, could distort retrospective duration and passage of time estimates due to the increased internal contextual changes during the social exposure. Though, due to the lack of systematic evidence, further research is highly warranted.

Taking a step further, although anxiogenic states have been found to have debilitating effects on performance, the exploration of their potential beneficial impact is still on its infancy. Even though there is no universal description of beneficial stress (i.e., *eustress*), the American Psychological Association (APA) defines *eustress* as the positive reaction to stressors, that implicates optimal levels of stimulation (APA Dictionary of Psychology, n.d.). In a recent cross-sectional study in 183 Malaysian university students, positive academic stress (i.e., *eustress*) was found to significantly benefit academic performance (Chua et al., 2018). Similarly, Al Majali (2020) showed that average positive anxiety levels lead to better academic outcomes, attributed to students' high internal motives for learning and sense of competence. Overall, these findings postulate that *eustress*, linked with development motivation, resilience, and self-efficacy, might serve as an adaptive mechanism that enables individuals to work on their optimal level of productivity and effectiveness (Chua et al., 2018). Yet, its role on perception and experience of time remains an open question.

To fill the gaps in the literature, the current study aimed to explore the individual differences on retrospective duration and passage of time judgments, as a function of social stressors. Given that public speaking has been indicated as the most prevalent subtype of social phobia (Aune et al., 2022), frequently observed in academic environments (Aune et al., 2022; Grieve et al., 2021), participants in this study had to deliver a presentation in front of an audience, as part of a university course or their teaching duties. We used a retrospective temporal protocol, thus, individuals were informed and requested to make duration and passage of time judgments about their presentation, *after* the latter had been completed. Based on previous literature on stress and timing, we investigated whether (i) higher levels of public speaking anxiety would predict temporal dilation (van Hedger et al., 2017). Moreover, considering that duration and passage of time estimates might share common retrospective memory mechanisms (e.g., Martinelli & Droit-Volet, 2022), we examined whether (ii) individuals with higher levels of public speaking anxiety would experience a slower passage of time. As somatic symptoms (Antony & Swinson, 2017), number of presenters (Murali et al., 2018), academic level of the speaker (Ahmad et al., 2017; Hajjare & Abdu, 2020; Reta et al., 2020), preparation level, and mood (Droit-Volet et al., 2018) have previously been linked with social stress and time distortions, respectively, we included these variables in our model, for exploratory purposes, to evaluate their potential contribution in our working hypotheses. Finally, we also explored the potentially beneficial effects of public speaking *eustress* on participants' perception and experience of time.

2. Methods

2.1. Participants

Based on our a priori power analysis ($\alpha = 0.05$, $p = .80$, and $f^2 = 0.35$), a total sample size of forty participants was required ($N = 40$). We recruited fifty-two healthy adults ($N = 52$), if some participants may not comply with the instructions or drop out from the study. Our sample consisted of 38 females, aged between 18 and 59 years ($M = 25.81$; see Table 1). Being at least 18 years old and studying at a bachelor's, master's, or doctoral level, were the inclusion criteria. Participants that had to deliver a presentation as part of their course (Bachelor and Master students) or teaching duties (i.e., doctoral candidates) were invited to participate and treated in accordance with the principles of Helsinki Declaration. Informed written consent was provided, and the study was approved by the Ethics Committee of Pantheon University (No. 20/15-5-2022). Participant recruitment started 18/05/2022 and ended 07/06/2022.

2.2. Materials

2.2.1. Demographic information

In the first subsection of the questionnaire, we gathered participants' demographic information, such as their gender, age, and academic level (see Table 1).

2.2.2. Presentation information

The second part of evaluation consisted of presentation-related questions. More precisely, participants were asked to make a duration judgement on their presentation (i.e., estimate the duration of their presentation in minutes), followed by two passage of time judgments (i.e., how fast/or slow did time seem to pass during the presentation and how fast/or slow did time "feel" to pass during the presentation – "feel judgement"; Wearden, 2015). Of note, each presentation duration was recorded by one of the authors using a smartphone, in order to accurately calculate the actual, physical time of the former. The rest of the questions involved: type of presentation (i.e., individual or group presentation), presence of moderator, difficulty level, personal interest on

Table 1
Participants' characteristics stratified by type of presentation.

	Mandatory	Elective	Total	
	<i>n</i> = 38	<i>n</i> = 14	<i>N</i> = 52	
	<i>n</i> (%)	<i>n</i> (%)	<i>N</i> (%)	
	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>M</i> (<i>SD</i>)	<i>p</i> -Value
Sociodemographic Characteristics				
Age	24.66 (6.7)	28.93 (13.3)	25.81 (9.0)	0.27
Gender				0.12
Males	8 (21.1)	6(42.9)	14 (26.9)	
Females	30 (78.9)	8 (57.1)	38 (73.1)	0.33
Educational Level				
Bachelor's	23 (60.5)	11 (78.6)	34 (65.4)	
Master's	11 (28.9)	3 (21.4)	14 (26.9)	
PhD	4 (10.5)	–	4 (7.7)	
Public Speaking Anxiety Measures				
Public Speaking Anxiety	107.92 (21.1)	86.79 (29.8)	102.23 (25.3)	0.03
Confidence as Speaker	5.08 (3.0)	3.79 (3.2)	4.73 (3.0)	0.18
Self-Statements	37.16 (6.2)	40.86 (6.2)	38.15 (6.3)	0.06
Timing Measures				
Time Estimation (Accuracy)	1.05(0.30)	0.91(0.26)	1.02(0.29)	0.12
Passage of Time	3.18(0.98)	3.86(0.95)	3.37(1.01)	0.002
Feel Judgments	3.16(0.96)	4.14(0.95)	3.42(1.04)	0.03
MDMQ	113.55 (23.1)	128.36 (27.5)	117.54 (25.0)	0.06
SSS-8	9.53 (5.9)	5.29 (5.6)	8.38 (6.1)	0.03
EuStress	15.87 (6.4)	18.36 (8.0)	16.54 (6.9)	0.25
Presentation Duration	19.80 (15.4)	13.85 (12.2)	18.19 (15.5)	0.22

p value is the result of chi-square test or (M)ANOVA (Brown-Forsythe *F* test for age and public speaking anxiety), adjusted to 0.05. *M* = mean, *SD* = standard deviation. Numbers in bold indicate significant results (*p* < .05).

the topic presented, level of preparation in weeks, readiness, experience of public speaking (i.e., number of presentations in front of an audience), seeking of public speaking opportunities, and sleeping hours the night before the presentation.

2.2.3. Multidimensional Mood State Questionnaire (MDMQ)

To examine the role of participants' mood on duration and passage of time judgments during public speaking, we used the Greek translation of MDMQ, which was initially developed in German by Steyer et al. (1997). The questionnaire evaluates respondents' mood state at the time of administration (i.e., after public speaking), consisting of 30 items in a six-point Likert scale, ranging from 1 (i.e., "definitely not") to 6 (i.e., "extremely"). It covers three dimensions: emotional valence (i.e., content-superb), alertness (i.e., rested-highly activated), and stress/calmness (i.e., restless-absolutely calm). The negative values were reversed coded and the sum of all 30 items ranged from 30 to 180 (see Table 1). Higher scores indicate better mood, greater alertness, and calmness at the time of administration. In the current sample, the questionnaire presented high internal consistency (Cronbach's $\alpha = 0.95$).

2.2.4. Self-Statements During Public Speaking (SSPS)

SSPS is a trait measure, developed to assess fearful appraisals related with public speaking (Hofmann & Dibartolo, 2000). It is consisted by two 5-item subscales, the "Positive Self-Statements" (SSPS-P) and the "Negative Self-Statements" (SSPS-N), which are mainly derived from Social Interaction and Self-Statement Test (SISST). The latter is a valid and reliable tool for examining self-statements during social interaction. The sum of each subscale ranges from 5 to 25, with higher values indicating more positive self-statements during public speech. SSPS presents good internal consistency (Cronbach's $\alpha = 0.83$).

2.2.5. Personal Report of Public Speaking Anxiety (PRPSA)

We utilized PRPSA (McCroskey, 1970) to determine participants' anxiety levels strictly related to public speaking. It is a highly reliable instrument (Cronbach's $\alpha = 0.94$, test-retest reliability = 0.84), composed of 34 items, on a 5-point Likert scale, ranging from 1 (i.e., "Strongly Disagree") to 5 (i.e., "Strongly Agree"). The sum of all values lies between 34 and 170, with scores > 131 indicating high anxiety levels. The internal consistency (Cronbach's α) in the current sample was within the acceptable range (i.e., 0.6 to 0.8; Cronbach, 1951), at $\alpha = 0.63$.

2.2.6. Personal Report of Confidence as a Speaker (PRCS)

For the purposes of our study, we administered the short version of PRCS, consisting of 12-items that aim to evaluate individuals' behavioral and affective responses during public speaking (Hook et al., 2008). The questions are answered in a true-false format and the scores range from 0 (i.e., no fear of public speaking) to 12 (i.e., highest level of fear of public speaking). The internal consistency (Cronbach's α) was $\alpha = 0.78$.

2.2.7. Somatic Symptom Scale-8 (SSS-8)

SSS-8 is a valid and reliable self-reported questionnaire, consisted of 8 items on a five-point Likert scale (i.e., 0 = "not at all", 4 = "extremely"), that aims to evaluate somatic symptom burden during the past week of administration (Gierk et al., 2014). The latter is associated not only with medical conditions but also with psychological distress. The sum of all values range between 0 and 32, with scores between 16 and 32 indicating extreme somatic symptom burden. Thus, we included this measure in our study to assess the role of somatic symptoms on time perception and experience under social stress conditions. In the present study, good internal consistency was observed (Cronbach's $\alpha = 0.77$).

2.2.8. Eustress

Given the limited literature on the effects of positive stress (i.e., "eustress") and the lack of standardized instruments for eustress during public speaking, for the purposes of this study, we developed a self-reported 6-item questionnaire (i.e., adjusted from Distress-Eustress Scale; Branson et al., 2019), to evaluate participants' positive stress levels during the preparation and delivery of the presentation. Each item was measured on a five-point Likert scale, ranging from 1 (i.e., "not at all") to 5 (i.e., "extremely"), with higher eustress scores indicating more beneficial outcome for the respondent.

2.3. Procedure

Participants were invited and informed about the study procedure after conducting their presentation, which was either taking place as part of their study course or their teaching responsibilities at the university's facilities. They were instructed to fill in a questionnaire composed of eight subsections: 1) demographic information, 2) presentation information (including the retrospective temporal task), 3) Multidimensional Mood State Questionnaire (MDMQ; Steyer et al., 1997), 4) Self-Statements During Public Speaking (SSPS; Hofmann & Dibartolo, 2000), 5) Personal Report of Public Speaking Anxiety (PRPSA; McCroskey, 1970), 6) Personal Report of Confidence as a Speaker (PRCS; Hook et al., 2008), 7) Somatic Symptom Scale-8 (SSS-8; Gierk et al., 2014), and 8) Positive Stress, which will referred in the current work as "eustress" (adjusted from Distress-Eustress; Branson et al., 2019). The presentation duration varied between 3 and 70 min based on presenter's academic level and the purpose of the former, while the completion of the retrospective questionnaire lasted approximately 20 min. Of note, given that questionnaires 3 to 8 were not available for Greek-speaking respondents, they were translated according to the latest guidelines (see Tsang et al., 2017).

3. Results

The statistical analyses were conducted using SPSS version 26. Descriptive statistics were calculated, and sociodemographic characteristics were compared between individuals who performed mandatory and elective presentations, respectively (see Table 1), using chi-square for categorical variables and (multivariate) analyses of variance for continuous variables, with Bonferroni correction. If the assumption of homogeneity of variance was violated, a Brown-Forsythe F test was reported. Three stepwise regression models were run to investigate which anxiety-related factor better predicted altered temporal and passage of time judgments under conditions of social evaluation. Two mediation analyses were performed, using PROCESS Version v3.4 (Hayes, 2017), with public speaking anxiety levels as predictor, mood state (MDMQ) as mediator, and passage of time and “feel” duration (both referred here as passage of time measurements) as dependent variables. An exploratory one-way multivariate analysis of variance (MANOVA) was performed to examine whether there were differences between mandatory and elective presentations on temporal and passage of time judgments. Based on the outcomes, we run two subgroup mediation analyses including only individuals who performed a mandatory presentation, with public speaking anxiety as predictor, mood levels (MDMQ) as mediator, and passage of time measurements as dependent variables. Of note, given that public speaking anxiety parameters (i.e., public speaking anxiety, self-statements about public speaking, confidence as speaker, and eustress) and mood states derived from different scales and part of the former failed to meet the assumption of normality, for the stepwise and mediation models, we used their normalized z-scores based on the Rankit's function.

3.1. Participants' characteristics

Table 1 shows the sociodemographic characteristics of the sample among the different presentation types (i.e., mandatory or elective). Participants in the two presentation categories differ significantly regarding their somatic symptoms and passage of time measures. Since homogeneity of variance could not be assumed for public speaking anxiety levels: Levene's $F(1, 50) = 6.057, p = .02$, a Brown-Forsythe F test showed that during mandatory presentation, participants experienced higher anxiety levels than their counterparts in the elective presentation group (see Table 1).

3.2. Stepwise regression

To pinpoint the best predictors of altered timing under fear of social scrutiny, we utilized three stepwise regression models, summarized in Table 2. Starting with four measurements related to public speaking anxiety (i.e., public speaking anxiety levels, self-statements for public speaking, confidence as speaker, and eustress) that might theoretically be good predictors of altered retrospective time estimations, a stepwise linear regression model (Model 1, Table 2) was used to reduce them to 1, which was: increased public speaking anxiety levels as predictor for time dilation (see Fig. 1A).

In Model 2, the same four predictors were tested, with “feel” judgments as outcome variable. Results showed that increased public speaking anxiety is a significant predictor of a slower sense of time passing (see Fig. 1B). Finally, in Model 3 the predictors remained unchanged, with passage of time as the outcome variable. The stepwise regression approach reduced them to one, which was: higher public speaking anxiety levels as a factor that slows down the passage of time (see Fig. 1C).

3.3. Mediation analyses

Mediation analysis was run, with public speaking anxiety as predictor, passage of time as the dependent variable and mood states as the

Table 2

Results from three stepwise regression models.

Model/predictor	t	p	β	F test	df	R^2	Cohen's f^2
Model 1							
Public Speaking Anxiety	2.33	0.02	0.31	5.44	1,	0.10	0.1
					50		
Confidence as Speaker	-0.89	0.38	-0.22				
Self-Statements about Public Speaking	0.06	0.95	0.01				
EuStress	-0.84	0.41	-0.12				
Model 2							
Public Speaking Anxiety	-3.04	0.004	-0.40	9.24	1,	0.16	0.2
					50		
Confidence as Speaker	-0.17	0.87	-0.04				
Self-Statements about Public Speaking	0.25	0.81	0.05				
EuStress	-0.59	0.58	-0.09				
Model 3							
Public Speaking Anxiety	-4.29	<0.001	-0.52	18.39	1,	0.27	0.4
					50		
Confidence as Speaker	-0.42	0.68	-0.09				
Self-Statements about Public Speaking	1.08	0.28	0.20				
Eustress	-0.16	0.88	-0.02				

Numbers in bold indicate significant results ($p < .05$). Note. In Model 1, time perception (accuracy) was used as dependent variable. In Model 2, feel judgments (passage of time measure) were used as the dependent variable. In Model 3, passage of time was utilized as the dependent variable.

mediator (Table 3, Model 1). A second mediation analysis was run with the same predictor and mediator variable, yet with “feel” judgments as the dependent variable (Table 3, Model 2).

In both models, the “direct” effects of public speaking anxiety levels on passage of time and feel judgments, respectively, were not significant. Anxiety levels during public speaking significantly predicted mood levels (pathway a'), while mood levels significantly predicted both passage of time and feel judgments (pathway b'). There were significant indirect effects of anxiety levels on both passage of time measures, suggesting that the latter are mediated by mood states.

3.4. Exploratory analyses

Given the ecological nature of the social stressor (i.e., public presentation) and the retrospective nature of the timing task, an equivalent control group was not a realistic option. However, in order to further explore how individuals' duration and passage of time judgments are modulated by fear of social evaluation, we grouped our sample into two subgroups, which are going to be referred here as “experimental” and “comparison” group. The experimental group consisted of individuals who had to perform a mandatory presentation (e.g., lecture or course assignment), where their performance would be assessed by the course instructor, contributing to their overall course or doctoral evaluation. On the other hand, the comparison group was formed by individuals whose presentation was elective.

One-way multivariate analysis of variance (MANOVA) was conducted to determine whether there were differences between mandatory and elective presentations on temporal and passage of time judgments (both passage of time and “feel” judgments). A significant difference on timing was observed [$F(3,48) = 4.66, p = .01, \eta^2 = 0.23$], Wilk's $\lambda = 0.775$. Specifically, there were significant differences on passage of time [$F(1,50) = 4.88, p = .03, \eta^2 = 0.09$] and “feel” judgments [$F(1,50) = 11.09, p = .002, \eta^2 = 0.18$], showing that during mandatory presentation participants experienced a slower passage of time as compared to the elective group (see Table 1).

To further investigate the aforementioned associations within the experimental group, we run two mediation subgroup analyses (see Table 3, Model 3 and 4), with public speaking anxiety levels as predic-

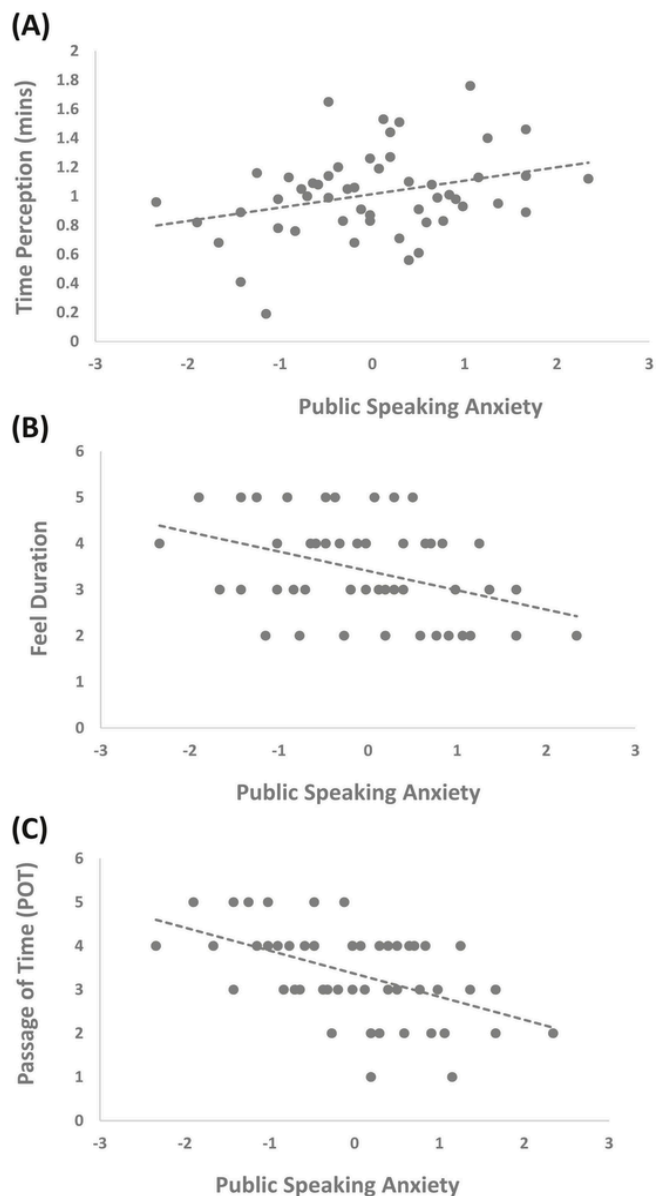


Fig. 1. Stepwise regression models. *Note.* (A) Stepwise regression Model 1, with time estimation (accuracy) in minutes as the dependent variable. (B) Stepwise regression Model 2, with “feel” duration as the dependent variable. (C) Stepwise regression Model 3, with POT as the dependent variable.

tor, mood state as mediator and passage of time, as well as feel judgments, as dependent variables, respectively (see Table 3). Similarly with Model 1 and 2 (see Table 3), the observation of significant indirect effects suggested mediation.

4. Discussion

Even though physical time is measured in standard units, its relationship with individuals' experience of perceived time is highly susceptible to context (e.g., van Hedger et al., 2017). Accumulating studies illustrate the effects of emotional valence and arousal on altered timing (e.g., Droit-Volet et al., 2004; Effron et al., 2006), yet the impact of social stressors on the latter, under naturalistic conditions, is severely neglected. To the best of our knowledge, the current study is the first to explore in retrospect the relationship between public speaking anxiety

Table 3
Summary of statistical mediation model between public speaking anxiety (IV) and passage of time (DV).

Model	Effect of IV on M(a)	Effect of M on DV (b)	Direct Effect (c) of IV on DV	Indirect Effect (SE) of IV on DV (a x b)	95 % CI (a x b)
	Effect (SE) p	Effect (SE) p	Effect (SE) p		
1 Passage of Time (N = 52)	-0.612 (0.112) < 0.001	0.411 (0.145) 0.0070	-0.276 (0.145) 0.06	-0.252(0.111) to 0.281(0.111)	-0.495 to -0.056
2 Feel Duration (N = 52)	0.612 (0.112) < 0.001	.459 (0.159) 0.0060	0.130 (0.418) 0.72	0.217(0.124)	0.536 to -0.103
3 Passage of time (n = 38)	0.550 (0.139) < 0.001	.562 (0.165) 0.0020	0.178 (0.166) 0.29	0.309(0.150)	-0.094 to 0.498
4 Feel Duration (n = 38)	0.550 (0.139) < 0.001	.395 (0.174) 0.030	0.220 (0.174) 0.21		-0.023

Note. IV: Independent Variable, M: Mediator (MDMQ), DV: Dependent Variable.

Numbers in bold indicate significant results ($p < .05$).

levels, time perception, and passage of time judgments of longer intervals. Analyses showed that increased levels of public speaking anxiety significantly predicted temporal overestimation and feelings of slower passage of time. Interestingly, the relationship between anxiety during the public speaking and passage of time measures (i.e., passage of time and “feel” judgments) was mediated by participants mood levels even after controlling for presentation type (i.e., mandatory or elective). Finally, the previously reported beneficial effects of stress on academic performance were not observed in relation to timing.

Several studies to date have established that fearful, threatening, or negative stimuli tend to give the impression that time is expanding or slowing down, an effect that is commonly referred to as temporal dilation (e.g., Droit-Volet et al., 2010; Grommet et al., 2011). Nonetheless, although we are highly social mammals, our experience of perceived time under social stressors has only recently been gaining attention. In their study, van Hedger et al. (2017) tested the effect of social stressors on time perception, using a modified version of TSST task in 42 healthy adults. Analyses revealed that individuals tend to overestimate time intervals of affective stimuli under fear of social evaluation. Yet, these observations were collected in a laboratory setting and participants were aware that they had to reproduce certain durations before and after stimulus presentation. Therefore, attention to time could also account for subjective interval expansion by enabling more “ticks” to be registered at participants' mental clock. Interestingly, our findings postulate that social stressors affect the experienced duration of longer intervals, where retrospective memory mechanisms are implicated (Droit-Volet et al., 2018), in a similar manner.

Emerging evidence propose that acute stress can influence memory (e.g., encoding and retrieval of episodic memories) several minutes later (Buchanan & Tranel, 2008; Gagnon & Wagner, 2016; Lupien et al., 1997; Schwabe & Wolf, 2014). The latter occurs due to the slower hypothalamic-pituitary-adrenal (HPA) axis release of glucocorticoids (Sapolsky et al., 2000), that are known from both animal (e.g., Diamond et al., 2007) and human studies (Het et al., 2005; Roozendaal, 2002; Wolf, 2009), to bind with dense glucocorticoid receptors in the hippocampus. Typically, the activation of HPA axis is observed over longer time scales, with cortisol levels peaking up to 40 min post stressor and returning to baseline approximately 60 min after stressor is terminated (Kemeny, 2003). That is, hippocampal-dependent memory processes are especially affected by stress-induced (exogenous administration or endogenous manipulation) glucocorticoid release (McEwen & Sapolsky, 1995). In the current protocol, we utilized a psychological

stressor under ecological conditions where participants had to deliver a public presentation as part of their university course or teaching duties without been informed about the study in advance. As expected, higher levels of anxiety during public presentation significantly predicted temporal lengthening. Overall, the impaired retrieval of temporal information following a social stressor might stem from biased attention to environmental or internal cues that are perceived to be threatening, increasing their probability of being encoded, while limiting attentional resources for timing the present (Diamond et al., 2005; Diamond et al., 2007; Sarigiannidis et al., 2020).

Given the fundamental role of self-focus attention and avoidance (e.g., eye gaze) in maintenance and treatment of social anxiety symptoms (e.g., Wong & Rapee, 2016), recent yet limited randomized controlled trials have explored the effects of attention guidance in public speaking distress habituation, using virtual reality (VR) technologies (e.g., Fehlmann et al., 2023; Wechsler et al., 2021). Interestingly, Wechsler et al. (2021) were the first to manipulate attention directionality in a public speaking VR scenario, using behavioral, eye-tracking, and physiological recordings. The results showed that attention training of high -nonclinical- socially anxious individuals on external social cues, can significantly alleviate public speaking anxiety and fear of negative assessment, while increasing eye-contact with audience and speakers' positive affect. Along these lines, in a subclinical group of adults with public speaking anxiety, repeated VR gaze exposure was also found to reduce their anxiety levels (Fehlmann et al., 2023). Nevertheless, none of those studies investigated the impact of gradual exposure to environmental fearful cues on perceived time. Taking into account, therefore, that attention is a robust modulator of interval timing under aversive conditions (e.g., Sarigiannidis et al., 2020), future randomized trials are needed to examine whether guiding individuals' attention towards and/or away from arousing cues could further enhance temporal accuracy, while reducing public speaking anxiety levels. The latter could enlighten the implication of bottom-up and top-down encoding, as well as consolidation mechanisms that simulate temporal information retrieval under conditions of acute social stress.

Based on recent studies depicting that temporal and passage of time judgments use common retrospective memory mechanisms (e.g., retrospective memory retrieval of the emotional context of the interval; Martinelli & Droit-Volet, 2022), it is not surprising that participants with higher levels of anxiety during their presentation felt that time was slowing down. This observation remained significant even after controlling for the type of presentation. More precisely, individuals who had to deliver a mandatory presentation reported higher anxiety levels and more somatic symptoms compared to speakers who conducted an elective presentation, which is also supported by previous literature (e.g., May et al., 2013). The former also experienced a slower passage of time in contrast to their counterparts. Thus, the current results indicate that fear of social exposure and judgement modulates our sense of time.

Considering the debilitating nature of psychological stress in everyday life, including educational and social contexts, identifying the mechanisms by which social stressors influence not only our temporal judgments but also our sense of time would be critical. Numerous studies performed in the milliseconds to seconds range have proposed that passage of time judgments rely on the affective state experienced during the interval. Individuals report a lengthening of time in the presence of highly arousing emotions (Droit-Volet & Berthon, 2017; Gil & Droit-Volet, 2012; Mella et al., 2011). However, in a study with longer durations the opposite effect was observed (Droit-Volet et al., 2018), suggesting that the impact of emotions cannot be generalized across all temporal scales. This could be partly attributed to the dynamic nature of emotions. More precisely, the emotion induced by an affective stimulus could be initially intense, but it decelerates rapidly, leading to a more permanent but less intense emotional state, which is frequently referred to as mood (Frijda, 2009). Yet, the short-lived effect of emotions on timing does not constitute a rule of thumb, as during frighten-

ing situations the emotional impact was found to be extended (Fayolle et al., 2015). Likewise, our study showed that for longer durations ($M = 18.19$, see Table 1), psychosocial threats decelerated the passage of time, which was explained by participants mood levels. In short, the current findings compose a real-life simulation of how our internal states, could account for our temporal experiences under social stressors across longer timescales. Future interventional studies could further evaluate the efficacy of emotion regulation strategies on altering individuals' sense of time during social exposure.

As with most of the studies, the current research is subject to limitations. More specifically, as far as we are concerned there are no self-reported instruments that evaluate respondent's mood and public speaking anxiety levels, as well as somatic symptoms, standardized for the Greek population. Therefore, well-documented instruments were selected and utilized in the study, that were translated in Greek according to the latest methodological guidelines (see Tsang et al., 2017). Moreover, given the lack of standardized instruments that measure eustress during public speaking, for the purposes of this study and inspired by Branson et al. (2019), we proceeded in the translation of a modified version of the *Distress-Eustress Scale*, following again the recent methodological recommendations (see Tsang et al., 2017). However, we could not oversee that the latter may account for our null findings. Hence, future investigation of eustress effects on subjective time, using a standardized tool, is highly warranted.

In conclusion, the current study provides preliminary evidence regarding the impact of social stressors on retrospective temporal and passage of time judgments under ecological conditions. Extending previous work, higher public speaking anxiety levels predicted both temporal dilation and slower passage of time. The latter remained significant when controlling for fear of evaluation, indexed by the type of the presentation. Specifically, those who delivered a mandatory presentation, whose performance was going to be assessed by the course instructor or supervisor, experienced a slower passage of time than those who conducted an elective presentation. These findings suggest that devoting more attentional resources on detecting potential -even mild- socially threatening cues during encoding/consolidation, might impair the retrieval of temporal information. Interestingly, participants mood was found to explain the relationship between public speaking anxiety levels and passage of time, respectively, implying that our mental states are involved in the altered experience of time under social threats. Finally, the current results could entail valuable implications, identifying the mechanisms that alter one's time percept under psychological stress could be useful for understanding the effects of the latter on educational and social contexts, as well as for the development of early intervention and prevention strategies, incorporating attention training and emotion regulation techniques that could potentially modulate the perception and experience of time of those who suffer from stress-related disorders.

CRedit authorship contribution statement

Efthymia Lamprou: Writing – original draft, Visualization, Validation, Resources, Investigation, Formal analysis. **Georgia Koupriza:** Writing – review & editing, Resources, Methodology, Investigation, Data curation. **Argiro Vatakis:** Writing – review & editing, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

Uncited references

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data, primary analyses, and supplemental materials are available on the Open Science Framework (<https://osf.io/n32sz/>).

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Open practices

Data, primary analyses, and supplemental materials are available on the Open Science Framework (<https://osf.io/n32sz/>).

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