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### Time judgment during a crisis

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**Time judgment during a crisis: The moderating effect of stress and ego network diversity  
on retrospective time judgments**

**ABSTRACT**

Forming accurate judgments is vital for management in general, and crisis management in particular. Despite its fundamental role in an organizational context, time judgments were not yet studied in a crisis context. Building on attentional-gate theory, we hypothesized that when decision-makers are under high information load, they can suffer from less accurate retrospective (i.e. recalled) time judgments. Furthermore, we expected this effect to be enhanced if stress and ego network diversity were also at higher levels. We tested our hypotheses in a within-subject experimental design (information load: low vs. high) where participants ( $N= 34$ ) role-played a disaster-response management team. We found that participants had less accurate and underestimating time judgments when information load was high, and this effect was more evident when stress levels were higher. Contrary to our expectations, the effect of information load on time judgments was not observed when ego network diversity was high, whereas a low level of diversity was associated with less accuracy under high information load. Our findings contribute to our understanding of the antecedents and boundary conditions of retrospective time judgments for crisis management.

*Keywords: time perception; duration judgment; attention; stress; ego network; diversity; crisis management; disaster response*

**Time judgment during a crisis: The moderating effect of stress and ego network diversity  
on retrospective time judgments**

Whether we call it a “crisis” or not, organizations need to face unexpected and potentially threatening events in order to thrive in a volatile environment (Bundy et al., 2017). Since a crisis is a major cause of uncertainty, organizations need to function with minimal objective criteria such as strict schedules. Time is a fundamental component in any organizational activity (Ancona et al., 2001; Bluedorn & Denhardt, 1988), especially pressing and of relevance in crises. However, at times of crisis, objective means of interpreting time might not preserve their functionality (e.g. following strict schedules become unrealistic under crisis). Thus, decision-makers rely on their subjective judgments on time to a greater extent in crisis situations.

One such judgment pertains to retrospective judgments on durations of past time intervals of events. Accurately estimating how long an activity took in the past can inform decision-makers to consider this duration in their future plannings (e.g. individuals can plan one hour for a future task if they recall that it took one hour in the past). Furthermore, accurate retrospective time judgments can enable better decisions for resource allocation. For example, within the first 72 hours of disaster response, governments and NGOs depend on reports of humanitarian response actors that contain when certain actions were completed in order to formulate funding decisions (United Nations Office for the Coordination of Humanitarian Affairs (OCHA), 2017). As such, retrospective time judgments carry high importance for crisis management.

Retrospective time judgments are influenced by the degree individuals devote attention to the passage of time (Block, 1992). As such, limited attention to the passage of time can result in less accurate retrospective duration judgments, that is, individuals’ subjective duration estimates can deviate from the objective duration (Castellà et al., 2017; Johnson & MacKay, 2019).

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Considering that dynamic and uncertain situations require more attentional resources from the individuals, retrospective time judgments can suffer greatly under crisis.

Organizations can aim to reduce uncertainty by providing more or more detailed information to individuals that operate under crisis (e.g. situation reports, factual data). The underlying assumption is that more information would alleviate uncertainty, and enable actors to make higher quality decisions. However, providing more information can limit the attention individuals can direct towards the passage of time, and therefore impair their retrospective time judgments. Previous studies have found that retrospective time judgments are influenced by increases in information processing (Block, 1992; Block, Hancock, & Zakay, 2010; Block & Zakay, 1997). Furthermore, the level of stress (Castellà et al., 2017; Hancock & Weaver, 2005) and changing between information processing types (Block & Reed, 1978; Martinez, 1992) were also associated with less accurate retrospective time judgments.

However, an important limitation is that the majority of these studies are conducted in controlled laboratory settings. Moreover, individuals mostly performed tasks in isolation where the influence of their social interactions on their time judgments was minimal. In crisis situations, however, individuals not only experience realistic pressure, but they also interact with a variety of actors that demand individuals to switch attention between task with different information processing demands. It is therefore essential to examine the relationship in a setting that has more external validity for management where actors are in a dynamic setting embedded in a network of interactions. The aim of this paper, therefore, is to investigate to what extent information load influences retrospective duration judgments within an actor-network operating under crisis. Examining time perception in a network setting can improve our understanding of time perception under frequent social interaction. Furthermore, understanding the drivers and

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boundary conditions of retrospective time judgments can enable managers to better plan and allocate (attentional) resources in times of crises.

Drawing from attentional gate model (Zakay & Block, 1995) we hypothesize that higher information load can lead to less accurate retrospective time judgments as it alters the attention that individuals can allocate at a given time. We further postulate that this relationship would be moderated by the level of stress, and ego network diversity of an individual. We test our hypotheses in an experimental setting where a disaster response coordination is simulated through a role-playing serious game.

Our paper has three major contributions. First, we provide suggestions for enabling more resilient crisis management by investigating antecedents and boundary conditions of time judgment during a crisis. Second, we expand our understanding of the interplay of crisis management context and cognition. Third, we bridge the literature on time perception in cognitive psychology with management and pioneer the investigation of retrospective time judgments in an organizational context.

## **THEORETICAL FRAMEWORK**

### **Time Judgement**

Cognitive psychologists have studied time perception by differentiating two overarching paradigms: prospective and retrospective time judgments (Block & Gruber, 2014; Block & Zakay, 1997). Prospective time judgments refer to estimating duration in the present (e.g. indicating when one minute is over) whereas retrospective time judgments refer to reporting a remembered duration (e.g. estimating a past time interval as one minute). One common phenomenon that is observed for both duration judgments is Vierordt's law (1878) which states the existence of cognitive bias in time estimations (Lejeune & Wearden, 2009). That is, there is a

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general tendency for shorter durations to be overestimated, whereas longer durations to be underestimated. Thus, time judgments are prone to cognitive biases.

Whereas the majority of the studies on time estimation investigated prospective time judgments, relatively much less is known about retrospective time judgments (Matthews & Meck, 2014). This is a limitation that holds great relevance for understanding judgments under crisis situations. Retrospective time judgments also inform the estimation of the duration of future activities, which is a fundamental cognitive basis for planning activities (Roy et al., 2005). Since crisis situations require planning activities as accurate as possible (Billings et al., 2016), expanding our understanding of retrospective time judgments is of high importance.

Several moderating factors were identified for retrospective time judgements. In their meta-analysis, Block and colleagues (2010) revealed that retrospective duration judgments are influenced by information processing difficulty, familiarity, attentional demands (i.e. dividing attention between tasks) and change in the type of information processing (e.g. from structural to semantic information processing) (Block, Hancock, & Zakay, 2010). In short, previous studies show that the extent of retrospective time judgment accuracy is contingent upon other cognitive processes that are impacted by the tasks individuals perform.

These studies, however, often reflect estimations that occur under controlled laboratory settings. Even when individuals estimate real-life events, (e.g. Castellà, Cuello, & Sanz, 2017; Yarmey, 2000), they are still rather isolated from other stimuli. This, however, is hardly the case in a crisis situation. Crises situations are characterized by a chaotic inflow of information with salient time-pressure to act. Moreover, individuals in crisis situations do not function in isolation but are part of a network that takes shape as for example a crisis management team. Furthermore, the decisions taken by one person are co-dependent in the communication and coordination of

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others. Since individuals' cognitions are greatly influenced by the characteristics of their physical and social surroundings, we cannot draw a direct link from the findings of laboratory studies to the crisis conditions. Therefore, it is necessary to test the assumptions of retrospective duration estimations in contexts that represent crisis conditions. This not only adds to the generalization of retrospective duration estimation findings but also help understanding factors that can inform estimations and planning (Roy et al., 2005).

A common model to explain time judgments is attentional gate theory (Zakay & Block, 1995).<sup>1</sup> The model differentiates between temporal tasks, where attention is devoted to perceiving time, and non-temporal task, where attention is devoted to cognitive tasks that are not related to time (e.g. reading a list of words, or solving a puzzle). The assumption of this theory is that perceiving the time passage requires distinct attentional resources than non-temporal tasks. The capacity of the attention, however, is limited. Therefore, devoting attention to non-temporal tasks hinders the attention that perceives the passage of time. As a result, when individuals need to devote relatively more attention to non-temporal tasks, their time judgements are less accurate.

The role of attention on time judgments is critical for crisis situations. Crises are characterized by various attentional threats (e.g. disruptive events, time pressure). On the other hand, individuals need to pay attention to an inflow of information and diligently process this

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<sup>1</sup> *Scholars studying time perception often denoted memory mechanisms for retrospective time judgments and attention mechanisms for prospective time judgments (Block & Gruber, 2014; Zakay, 1993). However, several researchers have also rejected this strict division. Block (1992), for instance, rejected memory-storage models for retrospective time judgments (Block, 1992). Alternatively, some researchers have claimed that these mechanisms are intertwined for both time judgment paradigms. For instance, for a retrospective time judgment, Castellà and colleagues (2017) used an attention-based model (i.e. pace-maker, accumulation model) to explain their findings as the attention during that past duration would influence how they experienced the duration, and thus, how they remembered it (Castellà et al., 2017). Similarly, Johnson and MacKay (2019) noted that attention was necessary for encoding the stimuli that would be remembered retrospectively (Johnson & MacKay, 2019). We follow this latter stream and argue that attention and memory are intertwined for retrospective time judgments as recalling an event is contingent on retrieval of the successfully encoded stimuli.*

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information for effective decision-making. In line with our reasoning, we formulate our research question as such: *“In crisis settings, to what extent does information load influence retrospective time judgments of individuals that are embedded in a network with different diversity levels?”*

### **Information Load and Time Judgment**

In less turbulent settings, organizations have more control over the amount of information load individuals receive. Organizations, for instance, can coordinate the timing of reports in a way that the information load is spread over time. A controlled timing of revealing information enables individuals to process information more adequately. Crises situations often lack this controlled timing of information inflow and processing. While some passages of time can be more “quiet” with less incoming information, an emerging event can result in an overflow of, oftentimes incomplete and inaccurate, information that individuals need to absorb. Thus, the amount of information load can vary greatly over time.

We posit that the extent of information load impacts the amount of attention that individuals can devote to the informing stimuli (e.g. reports). Attention is fundamental for encoding and processing, and further recall of the acquired information. When attention cannot successfully encode information, this results in further difficulties in processing and recalling information. Therefore, we suggest that the attention that is present at the time of information encoding would also influence the time when that information needs to be retrieved. When individuals need to recall information where they could not encode it easily (i.e. they could not devote sufficient attention to it due to information load), they would require more attentional resources to recall that information. Considering the propositions of attention-gate theory, we hypothesize that individuals would have less accurate retrospective time judgments when they need to encode and recall information that was presented with a higher load, compared to a lower



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load.

*H1a: Compared to low information load, high information load leads to less accurate retrospective time judgments.*

Time judgments not only vary in their degree of accuracy but also whether the judgment is an over or underestimation of the objective duration. Since Vierordt's law apply to retrospective time judgments (Lejeune & Wearden, 2009), we can expect a tendency to overestimate short durations and underestimate long durations. However, it is not clear in the literature for what is a short and long duration (Roy et al., 2005). Yarmey (2000) reported a tendency to overestimate for retrospective durations longer than 2.5 minutes, underestimating longer duration (Yarmey, 2000). On the other hand, Zakay (1993) operationalized any duration that exceeds a couple of seconds as long durations (Zakay, 1993). The operationalization of short and long durations matters as a meta-analysis found a difference in estimations between short (3 to 15 seconds) and longer durations (Block et al., 2010). Considering that retrospective duration judgments in crisis settings often require events that encompasses at least several minutes, we follow the operationalization of the meta-analysis and consider estimations longer than 15 seconds as long durations. As such, according to Vierordt's law, we expect a general tendency for retrospective time judgments to be underestimated regardless of the amount of information load.

*H1b: Retrospective time judgment of long durations leads to underestimation, rather than over-estimation.*

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### **Stress and Time Judgment**

An important factor that can influence attention, and therefore the impact of the level of information load on retrospective time judgments is stress. Stress can be defined as "a psychological reaction to the demands inherent in a stressor that has the potential to make a person feel tense or anxious". (McGrath, 1970). The general view on stress is that the anxiety that emerges from stress uses the attentional resources that can be used for the task. As a consequence, stress can narrow down attention (Chajut & Algom, 2003), and can interfere with encoding information (Staal, 2004). Due to the potential impact of stress on attention, we expect to see a difference in the effect of information load on retrospective time judgments under different levels of stress.

Under stress, attention is directed more towards the passage of time, resulting in an overestimation of durations (e.g. a shocking moment feels like hours) (Hancock & Weaver, 2005). However, while moderate levels of stress can increase attention, hyperstress can result in attentional drawbacks (Hancock, 1989). Due to constant time pressure during crisis situations, we can assume a prolonged state of stress that can represent a state of hyperstress (Ozel, 2001). As such, stress during crisis situations would be a factor that has more potential to limit attentional resources than increasing them.

Following attentional gate theory, we posit that stress would consume the limited attention that could be divided between temporal and non-temporal tasks. When stress is lower, more attentional resources are available for accurate time estimation. That is, despite the amount of attention required by processing high information load, it is still possible to devote some attention to the passage of time. Therefore, individuals can estimate past durations more accurately when that duration is associated with lower levels of stress. Alternatively, higher

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levels of stress limit the attentional resources that can be devoted to time perception. Stress can enhance the selectivity of attention (Chajut & Algom, 2003), which can result in prioritizing processing non-temporal information over the passage of time. Therefore under high information load, individuals would direct more attention to process information, less so for time perception. As a result, we expect to see an aggravated effect of information load on the accuracy of retrospective time judgements when the level of stress is higher.

*H2: The level of stress moderates the relationship between information load and retrospective time judgment accuracy, where the negative effect of information load on retrospective time judgment accuracy is stronger under higher levels of stress.*

### **Ego Network Diversity and Time Judgment**

Besides the *amount* of information load and stress, another relevant factor that intervenes with attention is *variety* of information content. Crises management often requires communication between organizations and individuals that are nested under different stakeholder groups (Hancock, 1989). In a disaster-response setting, government, NGOs, international organizations and local communities exchange information with varying content. Therefore, an individual might process information about different content when he or she interacts with a representative of an organization from a different stakeholder group (Daft & Macintosh, 1981). As such, the variety of information an individual receives can depend on the diversity of actors he or she is in contact with.

We suggest that an individual's embeddedness in a network with diverse stakeholder representatives enhances the need to process a wider array of information content. However, processing diverse information can come with attentional costs (van Knippenberg et al., 2015). Individuals need to encode, recall, and connect information from different domains. Building on

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attentional gate theory, we suggest processing information with diverse content would use the attentional resources that are necessary for an accurate time judgement under high information load. We posit that an individuals' ego network diversity (i.e. more diverse stakeholder group representatives in one's communication network) would moderate the relationship between information load and retrospective time judgments. When ego network diversity is lower, individuals would be more likely to process a homogenous set of information content that consumes less attentional resources. The attentional costs that are spared from processing similar information can be devoted to forming more accurate time judgments. When ego network diversity is higher, on the other hand, attention should be devoted to processing diverse information content as well as, processing passage of time. Considering the limited attentional resources, retrospective time judgments would suffer more from the negative influence of information load when the ego network diversity is also high.

*H3: The level of ego network diversity moderates the relationship between information load and retrospective time judgment accuracy, where the negative effect of information load on retrospective time judgment accuracy is stronger under higher levels of ego network diversity.*

## METHOD

### Participants and Design

Participants were 34 students (6 male,  $M_{\text{age}} = 21.09$ , 1 participant dropped out at the second data measurement point) taking a bachelor level course at a large Dutch University. The experiment was embedded in a course activity that enabled participants to experientially learn various crisis-managements skills. Participants were required to role-play a simulated disaster-

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response situation and consequently write a report about their experiences. Participation in the research (i.e. completing the experimental survey) was voluntary.

The experimental design of the study was a within-subjects design, where the manipulation of low information load was administered first, and high information load condition was administered later.

### **Task and Procedure**

The exercise simulated a disaster response occurring in Timor-Leste where various role-players (e.g. government, UN, NGOs) organized themselves to coordinate a disaster response operation. The simulation was developed by a former United Nations humanitarian response member and had been previously applied for professional training purposes at crisis prevention centres in the world. Prior to the exercise, each participant was assigned a role profile that described their specific position and motivations. The aim of the simulation was to manage a timely and effective disaster-response, while each character pursued its individual goal.

The disaster response was simulated by the announcement of various events throughout the 8 hours of the exercise. Participants were informed on these events by injects (i.e. printed papers that document mails with the indicated recipients), PowerPoint slides, or personal announcement by the simulation trainer. The injects contained information, requests, and advice on various topics related to the crisis. Throughout the simulation, participants exchanged information, coordinated responses, and allocated resources between characters to respond to the unfolding events.

The experimental intervention was embedded in this activity at two time points (one the first half, one in the second half of the simulation). Participants were announced to pause their interaction to pay attention to the slides that are displayed on the main wall on the venue. These

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slides displayed information from Sphere Guidelines, which is a handbook for a humanitarian response standard. These standards indicate the required key actions and minimum requirements for needs such as nutrition, health, shelter, and hygiene. Participants were informed to pay attention to this information, however, they were not instructed that they would be asked to recall them at a later time. Around one hour after the presentation, they were invited to discuss with other participants on what they remember from the slides. Afterwards, they were given a survey link to answer the questions individually on their mobile phones. Each survey started with a memory task where participants needed to recall the specific information from the most recent presentation. The surveys continued with additional measurements for the experiment.

After the second survey, participants continued their simulation exercise. The next day, they were fully debriefed about the experiment.

### **Manipulation of information load**

We postulated that when information load is lower in presented stimuli, attention can be devoted more easily to encode the information. This, in turn, would result in an easier recall of that information in a subsequent memory task. Therefore, we manipulated the amount of information in each slide that contained the value to be recalled in the memory tasks.

The first slides set represented the low information load condition. 5 slides were presented for 30 seconds each, with two to three sentences (word count ranging from 28 to 42). One of the sentences indicated a specific value in bold fonts (e.g. “*The maximum distance from any household to a water source should be **500 meters***”). The second slide set represented the high information load condition. Again, 5 slides were presented for 30 seconds each with one sentence indicating a specific value in bold fonts. However, in this condition, each slide contained additional 4-5 sentences about key actions to take for a specific situation (word count

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ranging from 129 to 200). Therefore, the information load of the second set of slides were higher.

## Materials

The two sets of measurements were applied two times, representing low information load (LIL) and high information load (HIL), respectively.

**Time judgement accuracy.** Our target durations were the two time intervals while participants were performing the memory tasks (i.e. answering the 5 recall questions). For our dependent variable, we used the absolute difference between subjective duration estimates to the objective duration of these time intervals<sup>2</sup>.

*Objective duration.* Using the time recording feature of Qualtrics, and recorded how many seconds it took participants to submit each answer. For each condition, we summed the total submitting duration across 5 questions. This yielded an objective duration of the time interval. ( $M_{LIL} = 37.13$ ,  $SD_{LIL} = 22.52$ ;  $M_{HIL} = 62.33$ ;  $SD_{HIL} = 35.17$ )

*Subjective duration.* For participants' estimation of remembered time, we asked participants to indicate how many seconds they thought it took to answer the previous 5 estimation questions. ( $M_{LIL} = 34.94$ ;  $SD_{LIL} = 31.58$ ;  $M_{HIL} = 45.73$ ;  $SD_{HIL} = 47.38$ ).

As such, we obtained two duration judgement accuracy variables for low and high information load conditions. Higher values indicated less accurate retrospective time judgments ( $M_{LIL} = 19.38$ ,  $SD_{LIL} = 17.50$ ;  $M_{HIL} = 34.35$ ;  $SD_{HIL} = 26.58$ ).

**Stress.** At each survey, participants were asked to indicate the stress they experienced on a 5-point scale ("When the slides from the Sphere guidelines were presented, how much *stress* did you experience processing the information?"). ( $M_{LIL} = 2.38$ ,  $SD_{LIL} = 1.07$ ;  $M_{HIL} =$

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<sup>2</sup>  $\sqrt{(\text{objective time} - \text{subjective time})^2}$

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2.70;  $SD_{HIL} = 1.21$ ). In line with our reasoning that prolonged stress decreases attentional resources, we retrieved our stress variable from these measurements at two time points. Thus, we averaged the two measurements for our moderation analysis.<sup>3</sup>

**Ego network diversity.** At the end of the first survey (at the midpoint of simulation) participants filled in a communication network assessment. Participants were asked to indicate to what extent they communicated with each role-player on a scale from 0 (“no communication”) to 10 (“constant communication”). We coded responses above 5 as frequent contacts and constructed a directed ego communication network (mean indegree centrality = 5.03 ( $SD = 1.7$ ); network density = .15). We computed a Blau index which was based on participants’ indegree score in their communication network and each neighbor node’s stakeholder group as an attribute.

For the stakeholder group attributes, we used the character profiles of the simulation exercise. Each character in the exercise either represented government actors (e.g. Ministry of Education) ( $n = 6$ ), NGOs (e.g. Red Cross, PLAN International) ( $n = 14$ ) or strategic donors (e.g. UN, embassies) ( $n = 14$ ). Higher scores on the Blau index indicated that an actor was embedded in a more diverse set of stakeholders ( $M = .55$ ,  $SD = .09$ ).

## Analyses

We investigated the main effect of information load on time judgement accuracy (Hypothesis 1a) by a paired sample t-test using the deviation scores. Comparison using this variable clearly revealed how many additional seconds of deviation from the objective duration occurred when information load was higher. For examining the extent of over- or underestimation across conditions (Hypothesis 1b) we used the ratio of subjective to objective durations. This is a common computation used in the literature to overview the direction of estimation scores (Block et al., 2010).

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<sup>3</sup> The difference between the two stress measures was not statistically significant  $t(32) = 1.24$ ,  $p > .05$



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Hypotheses 2 and 3 predicted moderation effects where the dependent variable was a repeated measure. We tested each moderation effect using the SPSS MEMORE macro (Montoya, 2019). This macro tests model where the outcome variable is a repeated measure and the moderator is a between-subject measure. The macro yields model estimates for the moderator's effect on the difference score of the two repeated measures, effect of the moderator on the difference score at different levels of moderators (low, moderate and high)<sup>4</sup>, and the effect of the moderator on the two repeated measures separately. For each moderation analysis, we investigated whether the conditional effect of information load on duration judgement accuracy (i.e. lower deviation scores) was influenced by the three levels of our continuous moderators.

## RESULTS

### Manipulation Check

We manipulated the amount of information load by adding additional lines of sentences to the slides that contained the information to be encoded. Therefore, slides with additional lines of sentences represented the high information load condition. As such, our manipulation is rather objective. Lonati and others (2018) recommend that a manipulation check is only necessary when the manipulation can be interpreted subjectively differently (Lonati et al., 2018). Therefore, we did not administer a self-reported manipulation check but rather examined the objective data. The word count of slides in the high information load condition was significantly higher ( $t(4.31) = -9.6, p < .001$ ). Furthermore, participants took more time (25 seconds) to recall the values from the high information load condition ( $t(32) = -3.95, p < .001$ ).

### Analyses

Table 1 shows the correlation between the variables for each information load condition.

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<sup>4</sup> Three points of the continuous variables are selected using the mean and  $\pm 1$  standard deviation from the mean

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 Table 1  
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Hypothesis 1a posited that under high information load, duration judgements would be less accurate. The analysis supported our hypothesis,  $t(32) = -3.00, p < .01$ . On average, the deviation of duration judgements was less accurate (deviated 15.35 seconds more) when respondents estimated retrospective time in the high information load condition compared to the low information load condition. Hypothesis 1b suggested that both duration judgements would underestimate the objective duration. On average, participants indeed underestimated the duration when information load was high (mean subjective/objective duration ratio = 0.74,  $SD = .61$ ). On the other hand, when the information load was low, they were slightly overestimating the duration (mean subjective/objective duration ratio = 1.003,  $SD = .83$ ). Therefore hypothesis 1b was partially supported.

Hypothesis 2 posited a moderation effect of stress on the effect of information load on duration judgement accuracy. As such, the difference between the two duration judgement accuracy scores would be influenced by different levels of stress. To test this hypothesis, we examined the effect of stress on the difference scores (time judgement accuracy<sub>LIL</sub> – time judgement accuracy<sub>HIL</sub>) for low (1.63), moderate (2.55) and high (3.46) stress levels. When stress was low, the difference between the two scores was not significant. However when stress was moderate, this resulted in additional 15.35 seconds of difference in time judgements' deviation  $t(31) -2.99, p < .05$ . This difference increased to 19.36 when stress levels were high  $t(31) = -2.64, p < .05$ . Stress was not significantly related to time judgement accuracy when information load was low ( $F(1, 31) = 3.34, p = .07$ ), but it did significantly predict time judgement accuracy when information load was high ( $b = 10.41, F(1, 31) = 4.55, p = .04$ ). Therefore, when stress levels were moderate and high, the time judgements were less accurate in the high information load condition compared to low information load condition. Furthermore, our analyses indicate that stress was particularly detrimental to duration judgements when information load was high, but it was not related to

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duration judgement accuracy under low information load condition. These findings provide support for hypothesis 2.

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Figure 1

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Hypothesis 3 posited a moderation effect of ego communication network diversity on the effect of information load on time judgement accuracy. Ego network diversity did not statistically significantly predict the difference between the two time judgement accuracy measures. Furthermore, it did not significantly predict time judgement accuracy scores separately. However, the effect of information load on time judgement accuracy differed across the low (.46), moderate (.55) and high (.65) levels of diversity. When ego network diversity was low, it significantly predicted the difference between time judgement accuracy measures. That is, when participants' contacts were less diverse, this significantly resulted in less accurate judgements in the high information load condition ( $b = -17.41$ ,  $t(31) = -2.36$ ,  $p < .05$ ). This effect was alleviated as the participants' contacts become moderately diverse ( $b = -15.36$ ,  $t(31) = -2.94$ ,  $p < .05$ ). The influence of ego network diversity ceased to be statistically significant on high levels ( $b = -13.30$ ,  $t(31) = -1.80$ ,  $p > .05$ ). These findings suggest that lower levels of ego network diversity can enhance the negative effect of information load on time judgement accuracy. That is, participants provided less accurate time judgements when the information load is high, especially if they are surrounded by a more homogenous group of contacts. This finding is contrary to the expectations of hypothesis 3, which posited that higher levels of ego network diversity would result in a stronger impairing effect of information load on time judgment.

Our diversity measure, Blau index, is based not only on the number of stakeholder groups in ego's contacts but also the indegree centrality of the ego. Therefore, it is possible that the observed influence of ego network diversity on time judgement accuracy was stemming from the extent of received information by means of indegree centrality. If that is the case, we expected to see the same pattern when we ran the analyses with in-degree centrality scores. Indegree centrality did not influence the difference

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between the two scores. It also did not predict time judgement scores in either condition. However, when we examined different levels of in-degree centrality, we found a difference. Furthermore, this difference was not in line with our findings on the influence of ego network diversity. Low level of in-degree centrality (3.28) was not related to the difference between the time judgment accuracy. However when indegree centrality was moderate (4.97), it predicted an additional 15.36 seconds difference  $t(31) = -2.99$ ,  $p < .01$ . This difference increased to 19.56 seconds when the in-degree centrality was high (6.66),  $t(31) = -2.67$ ,  $p < .05$ . These findings concur with our reasoning that more incoming information can result in less accurate time judgements of individuals. But whereas higher levels of in-degree centrality hamper time judgements, the same pattern is not evident for ego network diversity. Higher levels of diversity were instead associated with higher levels of time judgement accuracy.

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Figure 2

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## DISCUSSION

Accurate judgments are vital for effective management under crisis situations. In this paper, we examined one important yet understudied judgment form, namely retrospective time judgments. We argued that accurate retrospective time judgments require adequate attention to the passage of time. However, due to the limited attentional resources, time judgments may not be accurate. We investigated the influence of three prevalent attentional drainers in a crisis situation: the level of information load, stress, and the degree of diversity of one's network. We hypothesized that higher information load would result in less accurate retrospective time judgments, and this effect would be enhanced under higher levels of stress and ego network diversity. We tested our hypotheses in an experimental setting where participants role-played disaster-response management. We found that higher information load resulted in less accurate retrospective duration judgments, and this effect was stronger when participants reported

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more stress. Surprisingly, we found the opposite effect for the hypothesis on the moderating effect of ego network diversity. The effect of information load on retrospective time judgments was prevalent when ego network was *less* diverse (i.e. low and moderate levels of diversity), whereas the moderating effect was not observed for high levels of diversity.

### **Theoretical Implications**

To our knowledge, our paper pioneers the examination of time judgment under crisis situations. We suggest and test several variables that can influence retrospective time judgments. Our findings demonstrated that higher information load leads to less accurate retrospective duration judgments. Our study examines an important cognitive bias that can influence one of the most fundamental perceptions at times of crises, namely retrospective time judgments. As such, we contribute to the nascent literature on cognitions during a crisis (Bundy et al., 2017). Furthermore, by examining the subjective interpretation of duration, we contribute to the growing literature on the role of time perceptions at organizational settings (Ancona et al., 2001; Bluedorn & Denhardt, 1988). Our findings demonstrated that higher information load leads to less accurate retrospective time judgments. In line with Vierordt's law, this deviation was in the form of an underestimation. On the other hand, retrospective duration judgments were almost accurate (i.e. minimal deviation) when information load was lower. Our findings demonstrate the importance of adequate attentional resources on retrospective time judgments. When individuals are loaded with information, this can increase the attention they need to devote to process this information (i.e. encoding and recalling). Consequently, they can allocate less attention to the passage of time, resulting in less accurate time judgments. Overall, our results are in line with the prediction of attentional gate model. We further support that attentional mechanisms are influential for not only prospective but also retrospective time judgments.

Our results add to our understanding of the impacts of stress on crisis management. Due to the nature of a crisis, stress is highly prevalent. Performing despite the potential negative impacts of adversaries lies at the core of resilient management of crisis situations (Williams et al., 2017). However,

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our understanding of how it impacts crisis management has been limited. We found that higher levels of stress were associated with the effect of information load on retrospective time judgments, whereas this association was not observed for low-stress levels. In other words, when stress levels were low, retrospective time judgments were more accurate irrespective of the information load. However, when stress levels were moderate and high, the level of information load influenced the extent of participants' retrospective time judgement accuracy. This finding is in line with the predictions of the attention gate theory. Higher levels of stress consume more attentional resources and can interfere with time judgments.

We also contribute to the literature on diversity by demonstrating its potential cognitive impacts. Previous research on organizational diversity has mainly focused on various performance outcomes (e.g. Díaz-García et al., 2013; Nielsen & Nielsen, 2013). To our knowledge, our study is the first to examine the link between ego-network diversity and time perception. We investigated whether ego network diversity moderates the influence of information load on recalled durations. We expected that a more diverse network requires more attentional demands due to the need to process a higher variety of information. Therefore, we expected that when information load was high, this would result in less accurate judgments for individuals with a diverse communication network. Our analysis with indegree centrality confirmed that an inflow of information (i.e. communication) demonstrated the expected pattern, but this pattern was almost reversed when the network was more diverse. Thus, contrary to our expectations, we found that higher diversity levels resulted in *more* accurate time judgments.

A potential explanation can be that by providing a more various information source to individuals, ego network diversity can actually spare attentional resources for time judgments. Being embedded in a diverse network could have provided participants access to the collective intelligence of the network (Woolley et al., 2010). That is, the overall information was stored, processed, and retrieved across the network, easing the attentional load on individuals. Individuals, therefore, could use the additional attentional resources to the passage of time, resulting in more accurate time judgments. This

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reasoning would also be in line with the literature on macrocognition where the collective mental models and transactive memory systems facilitate information processing (Fiore et al., 2010).

Another potential reason for the unexpected findings can be due to the limited room to observe changes in diversity scores. Considering that Blau index ranges between zero and one, the three levels of diversity in our sample represented a rather narrow, and a higher level of diversity. It could be that the effect of diversity might have a non-linear relationship when the range increases. For instance, Dahlin et al. (2005) found a curvilinear effect of national diversity in a team on the range, depth and integration of information use (Dahlin et al., 2005), suggesting that the relationship between diversity and information processing can be non-linear.

### **Practical Implications**

Our findings demonstrate the importance of coordinating the timing of information flow at times of crisis. We demonstrated that even though more information attempts to facilitate more quality judgments, it can have the opposite effect. If managers need to assure timely planning and coordination during a crisis, they need to ensure the accuracy of time judgments. By carefully timing when the information arrives at individuals, they can increase the accuracy of time perceptions. If individuals seem to be under heavy workload, it would be beneficial for time judgments to prioritize the dissemination of information at a given time interval. This way, information load would not congest at short time intervals and would be diluted over time. This means that managers need to be considerate about the overall workload of each individual and be strategic about the timing of when they reveal information.

Our results also suggest that stress can impair time judgments, and stress-reducing interventions can enable better planning and decision-making in a crisis context. An interesting line of research has also pointed out the role of meditative states (i.e. when stress and arousal are minimized) on time judgment (Thönes & Wittmann, 2016; Wittmann & Schmidt, 2014). Actively tackling stress with such mindfulness interventions – how impossible it seems during crisis situations, can provide essential benefits for time

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judgements. Indeed, Williams and others (2017) have reviewed that collective mindfulness practices can fuel resilience in the face of adversities (Williams et al., 2017). We further recommend that such mindfulness practices can be implemented when timing and planning activities are of high importance.

Last but not least, our findings indicate that a more diverse communication network helps individuals to maintain a more accurate time judgment when they are under high information load. Effective network-level coordination of information can facilitate harvesting the cognitive benefits of a diverse network. Furthermore, encouraging boundary-spanning activities during a crisis can also facilitate more accurate judgments of time.

### **Limitations and Future Research**

Our study spanned different literature streams and aimed to conjoin the internal validity of an experimental setting with the external validity of a crisis management situation. However, this middle ground comes with natural limitations as we had limited room to maximize both validities concurrently. Noting this general limitation, we find some points important for consideration.

One important limitation concerns the second retrospective duration estimation. An important distinction between retrospective and prospective time judgment paradigms is that participants are not aware of the need to pay attention to time at retrospective paradigms, whereas they are requested to do so at prospective duration judgments. Since our procedure for the second estimation task was similar (i.e. announcing that they would fill in a survey), participants might have expected the time estimation task that followed the memory task. One potential way to address this limitation is counter-balancing the order of information load. In our experiment, it was not possible to adjust the simulation exercise in a way we could further divide participants. Furthermore, due to our sample size, we wanted to maximize our statistical power by using our all sample as one group. Future studies, however, can consider using a counterbalanced design, to control for potential differences stemming from expecting a time estimation task.



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A second limitation concerns the procedure of our experiment. In both conditions, participants were given the chance to discuss with each other on what they remember from the previously presented slides. In the first session, this discussion took place solely before the memory task, while in the second session participants slightly extended this discussion to the time when they were filling in the memory task. This might have influenced the degree of difficulty they had with recalling the answers for the memory task. We inspected the accuracy of the responses to the memory task. The standardized deviation of response values from the correct values were higher in the second condition compared to the first condition, however, this difference was not statistically significant. Therefore, we cannot ensure an increased difficulty in recall for the high information load condition. On the other hand, participants did take more time to answer the second set of questions (on average 25 seconds longer,  $t(32) = -3.95, p < .001$ ). We consider this difference as a result of taking more time to recall the correct answers to the memory task. Future research can take additional measures to specify the underlying cognitive mechanisms.

## CONCLUSION

Forming accurate time judgments is a vital cognitive asset for organizations at times of crisis. In this paper, we presented the results of an experimental study that investigated the effects of information load on retrospective time judgments. We found that under high information load, individuals estimated a past duration more inaccurately compared to when they were under lower information load. Furthermore, we found that this effect was enhanced under high levels of stress, and low levels of ego network diversity. Our findings contribute to our understanding of the antecedents and boundary conditions of time perception in a crisis context.

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## Appendix

Table 1

*Means, standard deviations, and correlations*

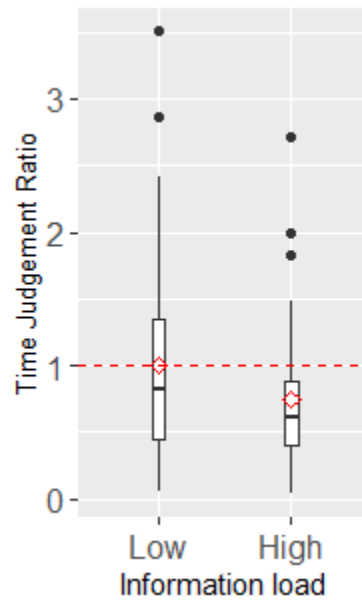
Variable	<i>M</i>	<i>SD</i>	1	2	3	4	5	6	7	8
1. Objective duration (LIL)	37.13	22.52								
2. Subjective duration (LIL)	34.94	31.58	.57**							
3. Time judgment accuracy (LIL)	19.38	17.50	.10	.25						
4. Objective duration (LIL)	62.33	35.17	.28	.19	.07					
5. Subjective duration (HIL)	45.73	47.38	.41*	.62**	.31	.55**				
6. Time judgment accuracy (HIL)	34.35	26.58	.08	.20	.17	.68**	.40*			
7. Indegree centrality	5.03	1.70	.07	.24	.15	.21	.36*	.24		
8. Stress	2.53	0.90	.12	.29	.29	.27	.35*	.36*	.03	
9. Ego network diversity	0.55	0.09	.07	.20	.02	.05	.23	-.08	.35*	.09

*Note.* *M* and *SD* are used to represent mean and standard deviation, respectively. \* indicates  $p < .05$ . \*\* indicates  $p < .01$ . LIL = Low Information Load; HIL = High Information Load. Time judgment accuracy: Higher values indicate less accurate judgments.

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Figure 1.

Overview of time judgement accuracy across low and high information load conditions.



The judgement ratio = subjective duration/objective duration. 1 represents perfect accuracy, higher values indicate overestimation and lower values indicate underestimation. The rhombuses on the boxplots represent the mean.



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Figure 2.

*Mean deviations in subjective duration judgements from objective duration across three levels of stress*

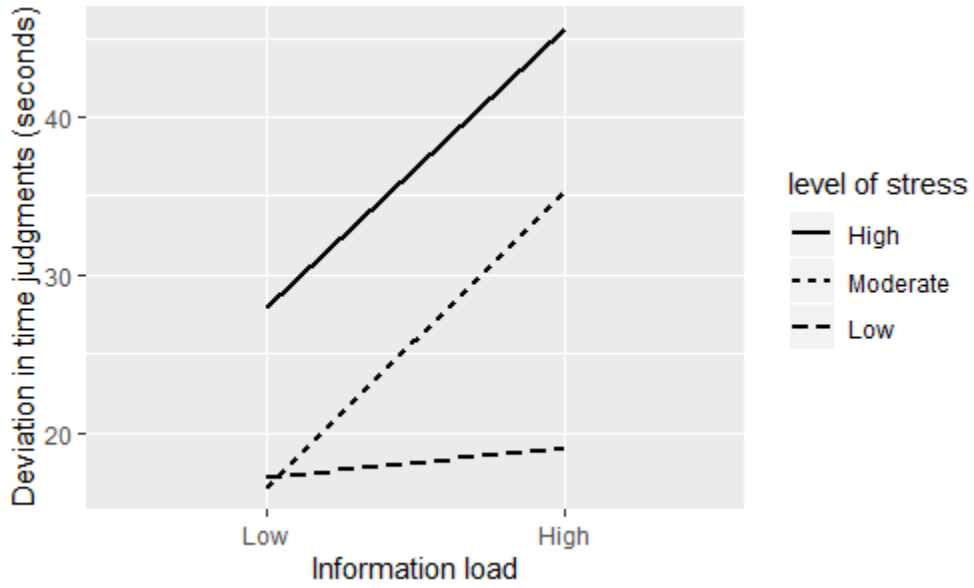


Figure 3.

*Mean deviations in subjective duration judgements from objective duration across three levels of ego network diversity*

