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The psychological impact of the pandemic: the effects of COVID-19 pictures on emotional processing

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Abstract

The impact of the COVID-19 pandemic continues to affect the lives of billions of people in recurrent waves. The present study aims to investigate the effects of exposure to COVID-related pictures on affective states, working memory performance, rumination, and intrusion. Negative emotions -- such as those aroused by the pandemic -- trigger a post-emotional elaboration depleting working memory resources required to perform other tasks. We expected a greater negative affect state, a greater impairment in working memory performance (as assessed by a visuospatial task), and a greater persistence of rumination and intrusion in participants exposed to COVID-19-related pictures as compared with emotional and neutral pictures. Results on a sample of 96 subjects show that when participants were requested to process COVID-19 pictures, their negative affective states increased over time (p<0.05), but the same does not hold for the emotional and neutral conditions. Furthermore, when participants were requested to process COVID-19 pictures, they exhibited a relevant persistence of long-term rumination (p<0.05), in particular in its deliberate form (p<0.05), and a significant persistence of intrusive thoughts (p<0.005). These considerations lead to serious concerns about post-event processing as a long-term consequence of the ongoing pandemic.

Keywords: COVID-19; negative affects; working memory; rumination; intrusion.

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Introduction

COVID-19 is a disease caused by severe acute respiratory Syndrome Coronavirus 2 (SARS-CoV-2) which has spread worldwide since its emergence in late 2019 in Wuhan, China. In a short time, this pathogen has caused a pandemic, which was declared by the World Health Organization (WHO) on March 11, 2020. Due to quarantine, almost all non-vital movement of people has been banned. As social distancing and "staying at home" became the main public policies during the COVID-19 health crisis, the imposed restrictions drastically changed people's social habits (WHO, 2020).

In their review paper, Brooks and colleagues (2020) described various causes of stress during long-term quarantine periods, including duration of isolation, fear of infection, anxiety, irritation and boredom, financial losses, and social stigma. All these factors contributed to extreme situational emotional distress (Geirdal et al., 2021), and increased prevalence of depression and anxiety due to reduced social contacts (Qiu et al., 2020; Rodriguez-Rey et al., 2020; Wang et al., 2020). According to a recent study by Lanciano and colleagues (2020), Italians experienced peak levels of long-term and persistent anxiety and worry. The most important risk perceptions were related to the future of the institutional economy and labor, followed by psychological risk perception.

It is still unknown how the pandemic – especially its second wave taking place in Italy in autumn-winter 2020-21 – has affected people's life. The chronic stress and overload of negative emotions caused by the exposure to the emergency period and the related consequences could lead to adverse physical and mental health outcomes in the long run (Schneiderman et al., 2005; Thoits, 2010). Indeed, negative events and resulting emotions have been demonstrated to conflict with task performance requiring cognitive and attentional resources such as working memory (Baddeley, 2003; 2012; Barrett et al., 2004; Okon-Singer et al., 2015).

Working memory (WM) is a cognitive system with a limited capacity. One of the main WM roles is to maintain goal-relevant information in mind, ready to be manipulated or employed, while keeping irrelevant information away (Goldman-Rakic, 1996; Baddeley, 2012). Baddeley describes four main components of WM: the central executive, the episodic buffer, and two storage systems, the phonological loop, which holds and manipulates speech-based information, and the visuospatial sketchpad, which performs a similar function for visual and spatial information (Baddeley, 2003; Baddeley et al., 2011).

Processing stressful experiences have effects comparable to secondary task sharing WM resources normally devoted to daily life tasks (Klein & Boals, 2001; Curci et al. 2013; 2015). Emotional stimuli are stressors that can require greater visual attention in comparison with neutral or positive material, evoking or increasing negative affective states, and post-emotional processes (Gross, 2013). This post-emotional processing commonly includes rumination and intrusions. Martin and Tesser (1996) defined rumination as a class of conscious thoughts that focus on a common instrumental theme and recur in the absence of immediate environmental needs. In contrast, intrusions are described as short-lived sensory impressions that are the direct result of the persisting impact of an emotional event (Ehlers et al., 2004).

Curci and colleagues (2013; 2015) investigated emotion and post-emotion processing – in the form of ruminative thoughts and intrusions – as resource-consuming processes affecting concurrent activities and entailing long-term consequences. In their studies, non-clinical participants were given a WM task before and after the presentation of negative vs. neutral information (a novel excerpt or a video clip). Rumination was evaluated immediately following the experimental induction.

Additionally, after a 24-hour delay, measures of rumination and intrusions were collected. Results demonstrated that the exposure to negative emotions significantly and durably affected participants' cognitive activity. Rumination moderated the link between the negative emotional state and the concomitant WM performance. Based on these findings, the authors claimed that ruminative activities exhaust WM resources, making them less available for concurrent tasks. Additionally, rumination tends to persist over time. At odds with rumination, individuals develop intrusions as a consequence of the emotional impact of these experiences, with no significant effects on WM load. These findings contribute to the investigation of the relationship between the cognitive and emotional systems, in terms of theoretical modeling of long-term emotional consequences in both everyday life and clinical settings.

Negative events such as the COVID-19 pandemic lend themselves well to an interpretation consistent with the above-reviewed evidence. COVID-19 pandemic reports and pictures spread like wildfire on social media, overlapping official communications and spawning a true "infodemic" (WHO, 2020). If COVID-19 emotional impact research is slowly making its way into literature (i.e., Montemurro, 2020; Canet-Juric et al., 2020), at the time of writing there are no studies about this overload of emotional material. It should be taken into account that, unlike other past epidemics and pandemics, the COVID-19 is the first pandemic with a huge amount of social media information. The impact in terms of the psychological well-being of the massive sharing of emotional material on social networks is still unknown.

Starting from Curci and colleagues' experiments (2013; 2015), in the present study, we aim to understand if the exposure to COVID-19 related pictures (compared to emotional and neutral material) would impact affective states, WM performance, and post-emotional processing (rumination and intrusion). Taking into account the above reviewed studies and the emotional impact and "proximity" of the COVID-19 pandemic - that is to experience a disastrous situation nearby and not only on the other side of the world (Hanusch, 2012) - COVID-themed photos are assumed to be more emotionally arousing than other generically emotional ones. Given our focus on visual stimuli (i.e., pictures), we used a WM visual analog task, such as that proposed by Curci and colleagues (2015), by applying a similar experimental procedure. When people experience stressful situations, such as the one we are living with the pandemic, related cognitive representations are expected to contend for WM resources with other task demands (Antrobus, 1968; Teasdale et al., 1995). Therefore, in running the present study we

aimed to show that the emotional and cognitive effects of the COVID-19 may represent long-term consequences of health distress associated with the same pandemic (Saltzman et al.,2020). Indeed, rumination can last for a long period after the original event and can be associated with depressive outcomes (Ehlers & Clark, 2000; Evans et al., 2007). Intrusions can have long-run consequences, too, so that they are considered to both cause and contribute to the persistence of psychopathological symptoms (e.g., Rachman, 2007; Brewin et al., 2010; Moritz et al., 2014). Difficulties in regulating intrusive thoughts are typically the starting point for illnesses such as PTSD and obsessive-compulsive disorder (Brewin et al., 2010). It follows that focusing on ruminative and intrusive processes triggered by the exposure to COVID-19 material is of great interest for the individual's psychological well-being at the time of the pandemic.

Hypotheses

The present experimental study was devised to investigate the effects of exposure to COVID-related pictures on affective states, WM performance, rumination, and intrusion after stimuli presentation. Following the above-cited studies on the post-emotional processing of negative experiences (see Curci et al., 2013; 2015), we expected:

H1) a greater negative affective state after the exposure to COVID-19-related pictures, as compared with emotional and neutral pictures;

H2) a greater impairment in WM performance (as assessed by a visuospatial WM task; Curci et al., 2015) after the exposure to COVID-19-related pictures, as compared with emotional and neutral pictures;

H3) a greater persistence of rumination and intrusion in individuals who have been exposed to COVID-19-related pictures as compared with exposure to emotional and neutral pictures.

Method

Participants

The study was given ethical approval by the Ethics Committee of the Department of Education, Psychology, Communication, University of Bari Aldo Moro, Bari, Italy, and executed according to the Declaration of Helsinki (No. ET-20-01). Participants signed informed consent before participating in the experiment. We used G*Power (Faul et al., 2007) to run an a priori power analysis for repeated-measures ANOVA between three groups with a power of 0.95 and effect size f = 0.20 (Correlation among repeated measures = 0.45) indicated a sample of 96 participants was needed. A total of 96 participants (50% women; M_{age} = 25.97, SD = 9.82), aged between 19 and 60 (M_{age} = 25.97, SD = 9.82), with an average level of education of 13.66 years (SD=2.06) were involved in the experiment.

Design

The between-subject factor of the design was Emotional Valence (COVID-19 vs. Emotional vs. Neutral). The dependent variables were: (1) Positive (PA-S) and Negative (NA-S) PANAS-S scores (Watson et al., 1988; Terracciano et al., 2003); (2) WM visual task indices; (3) Event-Related Rumination Inventory (ERRI, Cann et al., 2011); (4) Impact of Events Scale-Revised (IES-R, Weiss & Marmar, 1996). A repeated-measures assessment was adopted for PA-S and NA-S scores, WM measures, and ERRI scores.

Procedure, measures, and materials

The procedure included: (1) a Screening Phase; (2) a Pre-Test Phase; (3) a Test Phase using a visuospatial WM task; (4) an Experimental Manipulation Phase with emotion induction; (5) a Re-Test Phase for WM task; (6) a Post-Test Phase; and (7) a Follow-Up at a 24-hour delay.

Participants were recruited among University of Bari "Aldo Moro" students and experimenters' acquaintances. The whole procedure (40 minutes) was administered online due to COVID-19 restrictions, using Google modules and Teamview software. During the experimental session, the experimenter and the participant were connected via video call, with a shared screen to enable a correct administration of the task.

Three groups of 32 participants were randomly assigned to each of the three conditions (COVID-19 vs. Emotional vs. Neutral). The study involved the following phases:

- *Screening phase*: to rule out the effects of the individual's affectivity disposition, executive capacities, and depressive rumination style, participants were administered the Italian version of Positive and Negative Affect Schedule-Trait (PANAS-T; Watson et al., 1988; Terracciano et al., 2003), the Random Number Generation task (RNG; Ginsburg & Karpiuk, 1994) and the Italian version of the Ruminative Response Scale (RRS; Treynor et al., 2003; Palmieri et al., 2007).
- *Pre-test phase*: to evaluate the affective state at the moment in which participants are filling out the questionnaire, Positive and Negative Affect Schedule-State (PANAS-S; Watson et al., 1988; Terracciano et al., 2003) was administered by participants.
- *Test phase*: in this phase, we adopted a visuospatial task developed by Curci and colleagues (2015), administered through SuperLab Pro v.4.0 software to evaluate visuospatial WM performance.
- *Experimental manipulation phase*: participants were randomly allocated to one of three emotional conditions (COVID-19 vs. Emotional vs. Neutral), and requested to rate 13 pictures about how upset they were by each picture.
- *Retest phase*: immediately after watching the pictures, participants performed a new visuospatial WM task session to evaluate the effects of resource depletion on WM performance.
- *Post-test phase*: participants were re-administered PANAS-S. They also completed an adapted version of the Event-Related Rumination Inventory (ERRI, Cann et al., 2011),

a scale assessing two dimensions corresponding to intrusive and deliberate forms of rumination.

- *Follow-up*: Participants received by email an online questionnaire including ERRI and the Impact of Events Scale-Revised (IES-R, Weiss & Marmar, 1996), to measure the amount of protracted distress associated with a specific event in the form of intrusive processes. They were instructed to fill in the questionnaire exactly 24 h after they participated in the experimental session. All participants returned the questionnaire on time. One week after the lab session participants were debriefed in person or by video call.

Screening Phase

In this phase, we aimed to exclude individual differences in participants' affective states, executive performance, and ruminative tendencies before the experimental phase. To this purpose, participants administered PANAS-T (Watson et al., 1988; Terracciano et al., 2003), RNG (Ginsburg & Karpiuk, 1994), and RRS (Treynor et al., 2003).

PANAS-T is a scale that requires participants to evaluate, on twenty 5-point items (0 = not at all; 4 = completely), their general affective state along two dimensions, corresponding to Positive Mood (PA-T) and Negative Mood (NA-T). PA-T reflects the extent to which a person generally feels enthusiastic, excited, or active (i.e., *"How do you feel in general…determined?"*). NA-T reflects general subjective distress and negative mood (i.e., *"How do you feel in general… nervous?"*). Values range from 10 to 50, with lower scores representing lower levels of Positive/Negative Trait Affect and higher scores representing higher levels of Positive/Negative Trait Affect.

RNG assesses the individual's executive capacities. It requires participants to say aloud 120 random digits from 0 to 9, one per second, while trying to avoid rising, falling, odd, and even skip sequences. We used the RgCalc software, created by Towse and Neil (1998), to score the RNG and we obtained the RNG (Evans' Random Number Generator score) index.

RRS requires participants to rate on twenty-two 4-point scales (1 = never, 4 = always) how often they exhibit ruminative responses following sad or depressed feelings (i.e., "*Think about all your shortcomings, failings, faults, mistakes*"). Items from every scale were averaged into three composite indices for Brooding (Cronbach's a = 0.82), Reflection (Cronbach's a = 0.70), and Depression (Cronbach's a = 0.77).

Pre-Test Phase

To evaluate the affective state at the moment in which participants are filling out the questionnaire, PANAS-S (Watson et al., 1988; Terracciano et al., 2003) was administered.

PANAS-S is composed of two subfactors, PA-S and NA-S, as PANAS-T. These subfactors measure the degree of positive or negative affect (i.e., *"How do you feel in this moment…active/ afraid"*). Values can range from 10 to 50, with lower scores representing lower levels of Positive/Negative Affect and higher scores representing higher levels of Positive/Negative Affect. Cronbach's a for both PANAS-T and PANAS-S ranges from 0.86 to 0.90 for PA items and from 0.84 to 0.87, with the test-retest correlation of 0.47-0.68 for the PA and 0.39-0.71 for the NA (Watson, 1988).

Test Phase

In this phase, we adopted a visuospatial task developed by Curci and colleagues (2015), administered through SuperLab Pro v.4.0 software. As with other dual tasks, this task was designed to capture differences in attention retention and interference resistance (Rosen & Engle, 1998) as measures of healthy people's executive functioning (Miyake et al., 2000). Given the visual nature of the stimuli to be processed (i.e., pictures), we used that visuospatial task to evaluate the effects of resource depletion on WM performance.

The task consists of sixty ideograms presented individually on the screen for 1000 milliseconds. Correct recognition of ideograms and their position on the screen contributes to the individual's score. Each ideogram is presented in one of the four quadrants into which the computer screen is ideally divided. The presentation of each ideogram is followed by a blank screen for 300 ms. Participants had to identify whether another ideogram presented in the middle of the screen was the same as the one presented just before or a different one. Then they had to use a computer mouse to mark the areas of the screen occupied by the ideograms just identified in the same order of presentation. The task involved three blocks of stimuli ranging from two to six ideograms. One point is awarded for correct recognition and identification of the screen position, for a total of 60 points for the whole task.

Curci et al. (2015) run a pilot study to evaluate the validity of this task as a measure of WM capacity applied to visuospatial stimuli (sample N = 17). The Visuospatial performance scores correlated with the index of the Corsi block-tapping test (Orsini et al., 1987; Kessels et al., 2000) as a measure of visual memory span (Spearman's rho = 0.59, $p < 0.05$), and with indices obtained from RNG (Ginsburg & Karpiuk, 1994), such as RNG index (*Spearman's rho* = 0.60, $p < 0.05$).

Experimental Manipulation Phase

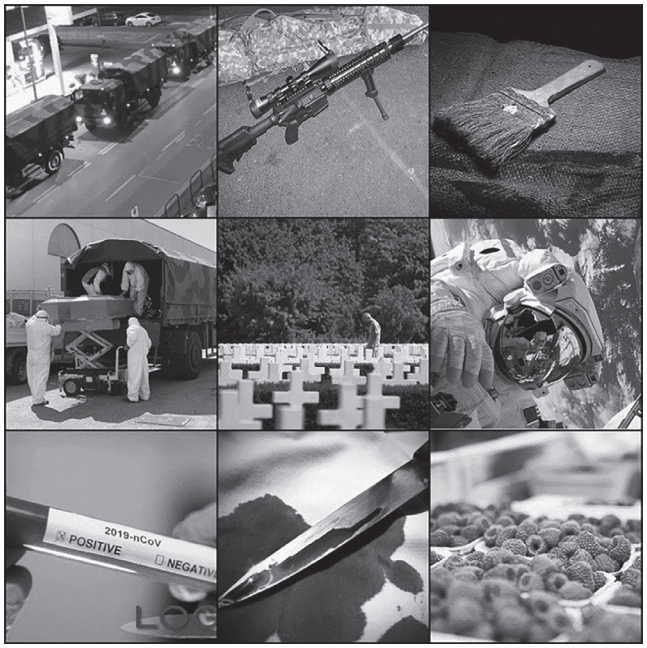
Participants were randomly assigned to one of the three conditions corresponding to COVID-19, Emotional, and Neutral themes. Within each condition, 13 pictures were presented on the computer screen using a PowerPoint macro to randomize the order of presentation (see Figure 1).

The whole set of 39 pictures was obtained from a pilot experiment, in which COVID-19 themed pictures were paired with generically emotional ones, chosen from the Open Affective Standardized Image Set database (OASIS; Kurdi et al., 2017). The emotional pictures were paired paying attention to visual similarity with COVID-themed ones. A sample of 60 participants (30 women) was requested to choose the most emotionally upsetting picture between

randomly presented couples of stimuli (COVID-19 and OASIS) and motivate their choice. The pictures evaluated as the most upsetting were selected for our study for a total of 26 pictures, 13 COVID-19-themed pictures ($M \geq 44.00$, $SD = 11.90$), and the associated 13 emotional pictures. A further set of 13 pictures was added for the neutral condition, selected from the OASIS database based on the valence and arousal scores reported by the authors and on visual similarity with COVID and emotional ones.

In the present experiment, after the presentation of each picture (one at a time, in randomized order), we asked participants to rate on a scale ranging from 0 (= not at all) to 10 (= completely) how upset they felt by that picture. This task was introduced to ensure that the emotional processing of the stimuli was effective[1]. Once the application was completed, participants moved on to the next slide.

Fig. 1. Examples of pictures used in the experimental session



Note. In the left column, there are three COVID-19 themed pictures; in the central column, there are three generically emotional pictures; in the right column, there are three neutral pictures.

Retest Phase

Immediately after the emotion induction, the visual WM task was performed again, which was identical to the previously performed one except for the ideograms adopted and their relative positions. This was done to investigate whether there were differences in WM performance after the picture exposure (Turner & Engle, 1989)[2].

Post-Test Phase

We used the PANAS-S to determine if there were differences between the pre-test and post-test phases in participants' affective states following the exposure to the pictures.

ERRI (Cann et al., 2011) questionnaire was adopted to measure rumination after the experimental manipulation phase. The test consists of twenty 4-point scales (1 = never; 4 = often). Total scores aggregate two sub-scales, corresponding to Intrusive and Deliberate rumination. Intrusive rumination refers to unwanted, disturbing thoughts related to an emotional experience (i.e., "*I thought about the pictures when I did not mean to*"); Deliberate rumination consists of the tendency to intentionally process an emotional experience (i.e., "*I forced myself to deal with my feelings about the pictures*").

Follow-Up

After 24-hour from the experimental session, each participant received an email with a follow-up questionnaire. In this session, the ERRI questionnaire was re-administered along with an adapted Italian version of the IES-R (Weiss & Marmar, 1997; Craparo et al., 2013), to assess participants' intrusive thoughts following the emotional induction of the experimental manipulation (i.e., "*Any reminder brought back feelings about it*"). All 96 participants completed the online follow-up questionnaire.

IES-R included twenty-two 5-point scales (0 = not at all, 4 = very much). All items were combined into three sub-dimensions (Intrusion, Avoidance, and Hyperarousal) and a total IES-R score. The measures show high degree of intercorrelation (r = 0.52 to 0.87, Creamer et al., 2003) and high levels of internal consistency (Intrusion: Cronbach's a = 0.87 – 0.94, Avoidance: Cronbach's a = 0.84 – 0.87, Hyperarousal: Cronbach's a = 0.79 – 0.91). Test-retest reliability ranged from 0.89 to 0.94 (Weiss & Marmar, 1997).

Results

Screening Analyses (PANAS-T, RNG, RRS)

A set of one-way ANOVAs was run to assess whether there were significant group differences in participants' executive capacities, tendency to depressive rumination, and affective states, with Emotional Valence (COVID-19 vs. Emotional vs. Neutral) as a between-subjects factor. The dependent variables were PANAS-T (PA-T and NA-T), RNG, and RRS indices (RRS–Brooding; RRS–Reflection; RRS–Depression; RRS–Total), measured at the Screening Phase. As Table 1 shows, no significant differences were found across the three groups on these variables.

[1] These data were not analysed for the purposes of the present study but are available upon request from the first author.

[2] Using the same test at both pre-test and post-test might have induced a possible learning effect, although Curci et al. (2013; 2015) showed that this effect was significantly more pronounced in participants exposed to neutral material as compared with participants exposed to emotional stimuli. In this sense, the repetition of the same task is not a limitation.

Tab. 1. One-way ANOVAs on measures at the Screening Phase[3]

Measures (Range; Cronbach's a)	COVID-19		Emotional		Neutral		*F*2 (partial η^2)	*p*
	Min, Max	Mean (*SD*)	Min, Max	Mean (*SD*)	Min, Max	Mean (*SD*)		
PA-T (0 – 4; 0.84)	0.60, 3.70	2.65 (0.69)	1.70, 3.50	2.53 (0.56)	1.10, 3.80	2.65 (0.58)	0.37 (0.01)	0.69
NA-T (0 – 4; 0.90)	0.00, 3.80	1.09 (0.82)	0.00, 3.40	1.48 (0.86)	0.00, 2.70	1.27 (0.80)	1.81 (0.04)	0.17
RNG index (0 – 1; 0.94)	0.29, 0.68	0.39 (0.10)	0.26, 0.76	0.38 (0.10)	0.23, 0.71	0.40 (0.11)	0.40 (0.01)	0.67
RRS–Brooding (1 – 4; 0.75)	1.00, 3.33	2.09 (0.52)	1.33, 3.50	2.26 (0.54)	1.00, 3.00	2.07 (0.49)	1.36 (0.03)	0.26
RRS–Reflection (1 – 4; 0.72)	1.00, 4.00	1.98 (0.67)	1.00, 3.20	2.06 (0.65)	1.00, 3.20	2.05 (0.70)	0.14 (0.00)	0.87
RRS–Depression (1 – 4; 0.86)	1.18, 3.45	2.03 (0.68)	1.09, 3.64	2.21 (0.58)	1.00, 2.91	2.13 (0.61)	0.50 (0.01)	0.61
RRS–Total (1 – 4; 0.89)	1.23, 3.23	2.05 (0.52)	1.27, 3.41	2.20 (0.47)	1.09, 2.86	2.08 (0.48)	0.89 (0.02)	0.41

Pre-Test, Test, Retest, and Post-Test Analyses

Pre-Test (PANAS-S)

To check the effectiveness of the experimental manipulation of participants' affective states, we ran two mixed-design ANOVAs with Valence (COVID-19 vs. Emotional vs. Neutral) as a between-subject factor, Pre-Post (Pre-test vs. Post-test phases) as a within-subjects factor, and with PANAS-S (PA-S and NA-S) as dependent variables (see Table 2). As regards PA-S, the main effect of Pre-Post was statistically significant ($F_{(2, 93)}$ = 13.36, p<0.01, partial η^2 = 0.13; see Table 3), in that PA-S scores significantly decreased over time ($M_{\text{Pre-test}}$ = 25.57, SD = 7.36; $M_{\text{Post-test}}$ = 23.40, SD = 8.76). By contrast, the main effect of Valence did not reach the significance level. Similarly, the interaction Valence*Pre-Post was not significant.

As regards NA-S scores, the main effects of both Valence and Pre-Post were not significant, while a significant interaction effect was observed ($F_{(2, 93)}$ = 4.49, p<0.05, partial η^2 = 0.09; see Table 3). Analyzing simple effects, NA-S scores for the COVID-19 condition were highly increasing over time ($F_{(1)}$ = 6.76, p<0.05, partial η^2 = 0.03), while scores for the Emotional and Neutral conditions did not show a significant change (respectively, $F_{\text{Emotional (1)}}$ = 0.98, p = 0.29, partial η^2 = 0.01; $F_{\text{Neutral (1)}}$ = 3.80, p = 0.12; partial η^2 = 0.07).

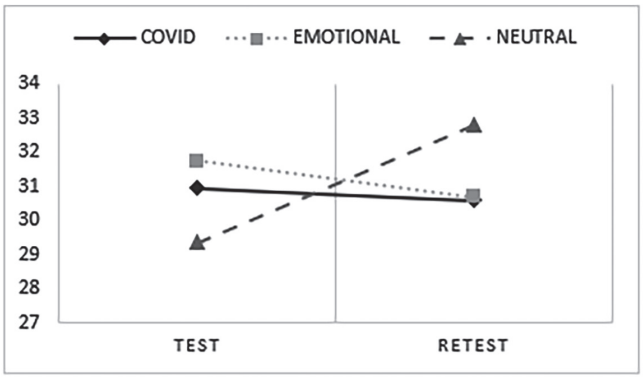
To sum up, the experimental manipulation of participants' affective states was found to be effective: when participants processed COVID-19 pictures, their negative affective states increased over time, while the same did not hold for the other two conditions of the design (see hypothesis 1).

Analyses of WM performance indices

We ran a 3x2 mixed-design ANOVAs with Emotional valence (COVID-19 vs. Emotional vs. Neutral) as a between-subject factor, Test-retest (Test vs. Retest phases) as a within-subject factor, and visuospatial WM task scores as dependent variables. The analyses revealed that there were no main nor interaction effects that reached the significance level ($F_{(2, 93)}$ =2.19 , p = 0.12, partial η^2 = 0.06; $F_{(2)}$ = 0.03, p = 0.97, partial η^2 = 0.001; $F_{(1)}$ = 0.52 , p = 0.47, partial η^2 = 0.01; see Table 3).

Given the non-significant effects, we can conclude that, although the observed mean differences for the WM index go in the expected direction (see Figure 2), hypothesis (2) was not confirmed.

Fig. 2. Mixed-design ANOVA on WM visual performance index



Post-Test and Follow-Up Analyses

Analyses on ERRI

We ran a set of mixed-design ANOVAs with Valence (COVID-19 vs. Emotional vs. Neutral) as a between-subject factor and Post-Follow-up (Post-test vs. Follow-up phases) as a within-subjects factor, on ERRI scores (Total, Deliberate and Intrusive) as dependent variables (see Table 4 and 5). As regards ERRI–Total and ERRI–Deliberate scores, the main effect of Valence was statistically significant (respectively; $F_{\text{Total (2, 93)}}$ = 4.35, p<0.05, partial η^2 = 0.09; $F_{\text{Deliberate (2, 93)}}$ = 3.65, p<0.05, partial η^2 = 0.07). For ERRI–Total scores, individuals in the Emotional condition scored the highest ($M_{\text{Emotional}}$ = 16.69, SD = 1.70), followed by individuals in the COVID-19 and Neutral conditions (respectively, $M_{\text{COVID-19}}$ = 14.55, SD = 1.70; M_{Neutral} = 9.75, SD = 1.70). The same pattern of results was

[3] Kurtosis and Skewness analysis were analysed for all measures collected. All indices ranged between -2 and +2. Analyses are available from the first author upon request.

observed for ERRI – Deliberate scores (respectively, $M_{Emotional}$ = 9.23, *SD* = 0.97; $M_{COVID-19}$ = 7.83, *SD* = 0.97; $M_{Neutral}$ = 5.55, *SD* = 0.97).

The main effect of Post-Follow-up was statistically significant for all ERRI indices (respectively, $F_{Total\ (1)}$ = 39.86, p<0.001, partial η^2 = 0.30; $F_{Deliberate\ (1)}$ = 22.65, p<0.001, partial η^2 = .20; $F_{Intrusive\ (1)}$ = 35.12, p<0.001; partial η^2 = 0.27), with scores decreasing from Post-Test to Follow-up, for Total ($M_{Post\text{-}test}$ = 17.00, *SD* = 11.30; $M_{Follow\text{-}up}$ = 10.32, *SD* = 11.16), Deliberate ($M_{Post\text{-}test}$ = 8.92, *SD* = 6.13; $M_{Follow\text{-}up}$ = 6.16, *SD* = 6.59) and Intrusive indices ($M_{Post\text{-}test}$ = 8.40, *SD* = 7.25; $M_{Follow\text{-}up}$ = 4.17, *SD* = 5.35).

A significant interaction effect was observed only for ERRI-Deliberate scores, with individuals in the Neutral and Emotional conditions showing a significant decline over time (respectively, $F_{Neutral\ (1)}$ = 20.91, p<0.001, partial η^2= 0.18; $F_{Emotional\ (1)}$ = 6.99, p<0.05, partial η^2= 0.07), at odds with individuals in the COVID-19 condition who exhibited a stable pattern of results ($F_{COVID\text{-}19\ (1)}$ = 1.05, p = 0.31, partial η^2= 0.01; see Table 5).

Taken together, these results support hypothesis (3): compared to neutral and emotional pictures, when participants processed COVID-19 pictures, they exhibited a relevant persistence of long-term rumination, in particular in its deliberate form.

Tab. 2. Descriptive analysis for the PA-S and NA-S scores (Pre- Post-test) and on WM indices (Test-Retest)

Measures (Range; Cronbach's a)	COVID-19		Emotional		Neutral	
	Min, Max	Mean (*SD*)	Min, Max	Mean (*SD*)	Min, Max	Mean (*SD*)
PA-S Pre-test (0 – 4; 0.89)	0.20, 3.90	2.73 (0.83)	0.50, 3.70	2.48 (0.76)	0.90, 3.60	2.46 (0.60)
PA-S Post-test (0 – 4; 0.91)	0.40, 4.00	2.34 (0.84)	0.50, 4.00	2.31 (0.88)	0.20, 3.90	2.37 (0.93)
NA-S Pre-test (0 – 4; 0.91)	0.00, 1.90	0.44 (0.48)	0.00, 3.40	0.83 (0.88)	0.10, 0.64	0.51 (0.66)
NA-S Post-test (0 – 4; 0.89)	0.00, 2.50	0.72 (0.75)	0.00, 3.20	0.94 (1.02)	0.00, 2.40	0.37 (0.69)
WM Test (0 – 60; 0.84)	16.00, 46.00	30.94 (9.34)	11.00, 47.00	31.75 (9.19)	13.00, 44.00	29.34 (9.48)
WM Retest (0 – 60; 0.83)	12.00, 46.00	30.59 (8.62)	17.00, 42.00	30.69 (7.24)	14.00, 53.00	32.78 (9.96)

Tab. 3. Mixed-design ANOVAs for the PA-S and NA-S scores at the Pre-test and Post-test and on WM indices and test-retest reliability coefficient

	Valence (a)		Pre-Post-test/ Test-retest (b)		a x b		Test-Retest Reliability
	$F_{2, 93}$ (partial η^2)	*p*	F_1 (partial η^2)	*p*	$F_{2,93}$ (partial η^2)	*p*	*Pearson r (p)*
PA-S Pre-Test / PA-S Post-Test	0.32 (0.01)	0.73	13.36** (0.13)	0.00	2.11 (0.04)	0.13	0.75** (0.01)
NA-S Pre-Test / NA-S Post-Test	3.07 (0.06)	0.05	1.44 (0.02)	0.23	4.49* (0.09)	0.01	0.69** (0.01)
WM Test / WM Retest	0.03 (0.001)	0.97	0.52 (0.01)	0.47	2.19 (0.05)	0.12	0.46** (0.01)

Note. *p<0.05; ** p<0.01

Tab. 4. Descriptive analysis for ERRI scores

Measures (Range; Cronbach's a)	COVID-19		Emotional		Neutral	
	Min, Max	Mean (*SD*)	Min, Max	Mean (*SD*)	Min, Max	Mean (*SD*)
ERRI–Total – Post-test (0 – 3; 0.90)	0.00, 2.15	0.85 (0.65)	0.15, 1.95	1.00 (0.50)	0.00, 1.85	0.75 (0.55)
ERRI–Total – Follow-up (0 – 3; 0.95)	0.00, 2.40	0.61 (0.61)	0.00, 2.20	0.66 (0.61)	0.00, 1.25	0.28 (0.35)
ERRI–Deliberate – Post-test (0 – 3; 0.84)	0.00, 3.00	0.83 (0.69)	0.10, 2.00	1.06 (0.52)	0.00, 2.00	0.78 (0.60)
ERRI–Deliberate – Follow-up (0 – 3; 0.92)	0.00, 2.60	0.73 (0.73)	0.00, 2.40	0.79 (0.72)	0.00, 1.50	0.32 (0.38)
ERRI–Intrusive – Post-test (0 – 3; 0.91)	0.00, 2.40	0.86 (0.79)	0.00, 2.40	0.95 (0.74)	0.00, 1.90	0.71 (0.64)
ERRI–Intrusive – Follow-up (0 – 3; 0.93)	0.00, 2.20	0.48 (0.55)	0.00, 2.30	0.54 (0.61)	0.00, 1.60	0.23 (0.38)

Tab. 5 Mixed-design ANOVAs on ERRI scores

Measures (Cronbach's a)	Valence (a)		Post-Follow-up (b)		a x b		Test-Retest Reliability
	$F_{2,93}$ (partial η^2)	*p*	$F_{1,93}$ (partial η^2)	*p*	$F_{2,93}$ (partial η^2)	*p*	*Pearson r (p)*
ERRI–Total – Post-test ERRI–Total – Follow-up	4.35* (0.09)	0.02	39.86** (0.30)	0.00	1.03* (0.02)	0.36	0.57** (0.01)
ERRI–Deliberate – Post-test ERRI–Deliberate – Follow-up	3.65* (0.07)	0.03	22.65** (0.20)	0.00	3.15* (0.06)	0.04	0.59**(0.01)
ERRI–Intrusive – Post-test ERRI–Intrusive – Follow-up	2.40 (0.05)	0.10	35.12** (0.27)	0.00	0.21 (0.004)	0.82	0.42**(0.01)

Note. *p<0.05; ** p<0.01

Analyses on IES-R

A set of one-way ANOVAs was run on the IES-R scores (Total, Intrusion, Avoidance, and Hyperarousal) with Valence (COVID-19 vs. Emotional vs. Neutral) as a between-subjects factor (see Table 6). Due to high skewness and kurtosis coefficients[4], we run bootstrapped one-way ANOVAs (stratified sampling for Valence and Sex, CI 95%, 5000 samples).

The main effect of Valence was significant for IES-R–Total scores ($F_{(2, 93)}$ = 6.29; p<0.001, partial η^2 = 0.12), IES-R–Avoidance ($F_{(2, 93)}$ = 7.59; p<0.001, partial η^2 = 0.140), and IES-R–Hyperarousal ($F_{(2, 93)}$ = 4.01; p<0.05, partial η^2 = 0.79). No significant effect was found on IES-R–Intrusive scores ($F_{(2, 93)}$ = 2.74; p = 0.07, partial η^2 = 0.06).

We run post hoc Bonferroni comparisons to assess if there were significant differences among subsamples' means. We chose this post-hoc test to avoid an inflate of type I error due to multiple comparisons and for its conservativeness.

For IES-R-Total score, post hoc Bonferroni comparisons demonstrated there was a significant difference for the Emotional (M_{Diff} = -8.72, 95% CI (-15.42, -2.02), p = 0.06) and COVID-19 conditions (M_{Diff} = -8.12, 95% CI (-14.82, -1.43), p = 0.012) as compared with the Neutral one (M_{Diff} = 0.59, p = 1.00), in that individuals in the Emotional condition scored the highest and individuals in the Neutral condition scored the lowest.

A similar pattern of results emerged for IES-R–Avoidance with individuals in the Emotional condition scoring the highest and those in the Neutral condition scoring the lowest. Indeed, Bonferroni post hoc comparisons demonstrated that there was a significant difference in this measure for Emotional (M_{Diff} = -4.53, 95% CI (-7.55, -1.51), p = 0.001) and COVID-19 conditions (M_{Diff} = -3.72, 95% CI (-6.74, -0.70), p = 0.01) as compared with the Neutral one (M_{Diff} = 0.81, p = 1.00).

For IES-R – Hyperarousal indices, individuals in the COVID-19 condition reached the highest levels, while participants in the Neutral condition reached the lowest. Bonferroni post hoc comparisons demonstrated that there was a significant mean difference of IES-R – Hyperarousal measures for COVID-19 (M_{Diff} = -2.22, 95% CI (-15.42, -2-02), p = 0.04) compared with the Neutral condition (M_{Diff} = 0.16, p = 1.00). Other differences were not statistically significant (all p_s>0.05).

These findings support hypothesis (3), by indicating that there was a greater persistence of intrusions in individuals who have been exposed to COVID-19-related material compared with those exposed to neutral ones.

Tab. 6. One-way ANOVAs on IES-R scores

Measures (Range; Cronbach's a)	COVID-19		Emotional		Neutral		$F_{2,93}$ *(partial* η^2*)*	*p*
	Min, Max	Mean (*SD*)	Min, Max	Mean (*SD*)	Min, Max	Mean (*SD*)		
IES-R–Total (0 – 4; 0.91)	0.00, 2.27	0.60 (0.61)	0.05, 1.68	0.62 (0.55)	0.00, 1.00	0.23 (0.28)	6.29** (0.12)	0.003
IES-R–Intrusion (0 – 4; 0.84)	0.00, 2.88	0.64 (0.70)	0.00, 2.38	0.65 (0.65)	0.00, 1.88	0.34 (0.44)	2.74 (0.06)	0.070
IES-R–Avoidance (0 – 4; 0.80)	0.00, 2.25	0.70 (0.66)	0.00, 3.00	0.80 (0.76)	0.00, 1.38	0.23 (0.36)	7.59** (0.14)	0.001
IES-R–Hyperarousal (0 – 4; 0.85)	0.00, 2.50	0.48 (0.69)	0.00, 2.17	0.38 (0.59)	0.00, 0.83	0.09 (0.21)	4.01* (0.08)	0.021

Note. *p<0.05, **p<0.005.

[4] Skewness and kurtosis analysis for the cited measures resulted for IES-R-Total scores, Skewness = 1.34 and Kurtosis = 1.30; for IES-R-Intrusive scores, Skewness = 1.60 and Kurtosis = 2.37; for IES-R-Avoidance scores, Skewness = 1.41 and Kurtosis = 1.63; for IES-R-Hyperarousal scores, Skewness = 1.95 and Kurtosis =2.96.

Discussion

The current study experimentally examined the hypotheses that exposure to COVID-19-related pictures is related to changes in affective states, WM performance, rumination, and intrusion as compared with emotional and neutral pictures. Following our prediction (1), we observed that when participants processed COVID-19 pictures, their negative affective states increased after the manipulation and over 24 hours as compared to individuals who processed emotional and neutral pictures.

Furthermore, we observed that exposure to COVID-19 and emotional material is linked to a decrease in visuospatial WM scores, but the results of our analyses on the WM index were not statistically significant so that our hypothesis (2) was not confirmed. This might probably be due to the visuospatial task adopted as concurrent to emotional processing. Some studies demonstrate that visuospatial tasks temporarily reduce the intensity of emotional material to process (Andrade et al., 1997; Kavanagh et al., 2001; Kemps & Tiggemann, 2007). Andrade and colleagues (1997) challenged nonclinical samples to construct emotive imagery triggered by pictures of conflicts, death, and disasters in an experimental imitation of post-traumatic stress disorder. They also assessed clarity, vividness, and emotional reaction to these photos. During the imaging phase, individuals completed a concurrent task designed to load the visuospatial WM. Visuospatial task completion reduced not only the clarity and the vividness but also the emotional impact of upsetting pictures. However, van den Hout et al. (2001) replicated this study and demonstrated this vividness and emotional reductions persisted only immediately after the visuospatial task. In this sense, our results on rumination could be considered as accounting for post-emotional processing occurring when the effect of the visuospatial WM task wears off.

Our results also showed that post-event rumination, especially in its deliberate form, was higher for individuals who viewed and rated emotional pictures as compared with individuals exposed to COVID-19 and neutral stimuli. However, at odds with rumination for emotional and neutral images, rumination following exposure to COVID-19 pictures appeared to persist over time. As regards intrusion indices, the Hyperarousal scores were higher when participants in the COVID-19 condition are compared to the sample assigned to the neutral condition. Taken together, these findings support hypothesis (3): the greatest persistence of rumination and intrusion was observed for individuals who have been exposed to COVID-19-related and emotional material. Major life events, especially negative ones that challenge the individual's assumptive world beliefs, require cognitive processing (Janoff-Bulman, 1992). Watson and Clark (1984) described individuals high in Negative Affect as also tending to ruminate and dwell on their mistakes. These results are in line with Curci and colleagues' outcomes (2015) and with the theoretical and empirical distinction between rumination and intrusion (Evans et al., 2007). Indeed, the former appeared more like a cognitive process consisting of repetitively thinking about an emotional event and influenced by the individual's WM resources, whereas the latter mainly consisted of sensory impressions of short duration rapidly arising from the original experience as a consequence of its emotional impact (Ehlers & Clark, 2000; Hackmann et al., 2004). The effects on the intrusive component of rumination should be read in conjunction with results on intrusions, as assessed by IES-R. Intrusive rumination is different from the intrusion of sensory-perceptual material related to a traumatic experience. Intrusive rumination might be conceptualized as a recurrent attempt to understand the impact of a stressful experience to justify its meaning (Calhoun et al., 2010). By contrast, intrusions are instances of involuntary or direct retrieval, as opposed to voluntary retrieval, in that they pop up spontaneously rather than as a result of a conscious effort (Berntsen, 2009; Mace, 2007). It follows that IES-R scores are systematically higher for emotional material (also including COVID-19 pictures) in comparison with neutral stimuli. In our study, participants do not seem to develop repetitive and insistent forms of thought concerning what was shown to them (i.e., *"Why am I exposed to these pictures?"*) but the COVID-19/emotional scenes involuntarily re-emerge into awareness in the form of intrusions (IES-R).

The style in which a person engages in cognitive processing in the aftermath of a stressful life event has significant consequences for the psychological impact of the same event. Event-related rumination influences people's health and well-being in life crises and transitions. In dealing with emotional experiences, the two forms of ruminative thoughts, Intrusive and Deliberate, have distinct effects on post-traumatic outcomes (Schaefer & Moos, 1992; Cann et al., 2011). Deliberate rumination demands a conscious review, re-examination, and creation of alternative viewpoints to enable progress and it is associated with generally favorable outcomes such as post-traumatic growth (Ikizer et al., 2021; Tedeschi & Blevins, 2015). Continuous exposure to COVID-19 pandemic-related material can keep the rumination persistent, while the mass media plays a crucial role in spreading information on the pandemic (Garfin et al. 2020). Individuals prone to rumination, in such a contingency, may increase their attempts to manage emotions, resulting in a decreased psychological wellbeing, and become stuck in the deliberate rumination when personal resources are insufficient to reprocess the event (Ehlers & Clark, 2000). Continued deliberate ruminating could reflect a long-term struggle with negative emotions, resulting in distress mediated by current intrusive ruminations (Chan et al., 2011).

As to intrusive thoughts following COVID-19 exposure, our findings also support the general hypothesis that the COVID-19 pandemic is a mass traumatic event that moves people to a hypervigilant rather than avoidant stance (see Sanchez-Gomez et a., 2021). High levels of intrusive thoughts are linked to sustained or increased discomfort, as well as to a failure to deal well with the experience (Ehlers & Clark, 2000; Elwood et al., 2009; Taku et al., 2008). The pandemic scenario led people to be repeatedly reminded of the negative occurrence, making them feel alarmed and experiencing excessive vigilance. Furthermore, because individuals are unable to escape the traumatic occurrence and eliminate the stressor, they experience unpleasant emotions, as fear and anxiety, which have a severe impact on their mental health (Sanchez-Gomez et al., 2021). Recent empirical studies have provided findings

consistent with the idea of a traumatic impact of COVID-19 on the general population (Casagrande et al., 2020; Ikizer et al., 2021; Karatzias et al., 2020; Liu et al., 2020).

Our study has four main limitations. Firstly, we did not systematically consider individual differences in terms of WM capacity, except for the RNG assessment during the Screening Phase. Curci and colleagues (2013) showed that the individual's availability of WM resources was significantly associated with the presence of ruminative thoughts both immediately after an emotional event and 24 hours later. The role of the individual's cognitive and executive resources needs to be taken into account in modeling the role of WM resources in post-emotional processing.

Secondly, in studies conducted by Brewin and Beaton (2002) and Brewin and Smart (2005), the influence of intrusive formations on WM performance was only examined when participants were expressly instructed to suppress intrusive thoughts. This type of instruction was not given in our study, so any lack of significance might also be attributed to the structure of the experiment. We set up our experiments by aiming to investigate post-emotional processing of experiences that resemble daily life occurrences.

Thirdly, we did not ask for information about past experiences related to COVID-19, for example about participants' or relatives' previous infection, vaccination access, or attitude toward COVID-19 quarantine or vaccination campaign. These variables would have played a role in increasing the ruminative processes in participants. The present study was carried out from February until April 2021, i.e., in the middle of a period of restrictions and red zones institution corresponding to the COVID-19 second wave in Italy. The difficulty of carrying out the administration of a remote computerized task limited the experimental procedure, also given the need to concentrate the data collection in a short period characterized by repeated changes.

Finally, COVID-19 pictures taken alone could be less powerful to induce emotion, while in an "infodemic" context, both emotional words and pictures continuatively crash on the screens, destabilizing everyday life. Given the extreme diffusion of COVID pictures, there could be a desensitization effect, where these pictures are not as destabilizing compared with the generically emotional ones, which are "new".

Despite these limitations, our study reports interesting results from both a clinical point of view and for future policies contrasting long-term consequences of the pandemic. We are continuously overwhelmed with pictures in a dynamic crisis setting, which often contains a variety of terrible and disturbing information. Users usually express their negative emotions on social media, according to content analysis of blogs and Twitter posts related to disasters (Macias et al., 2009). Continuously sharing unpleasant content and stressful experiences may eventually improve a vicious circle of negative psychological consequences (Zhao & Zhou, 2020).

One year after the outbreak of the pandemic and the onset of the lockdown, COVID-19 material continues to impact the individual affective states and ensuing ruminative and intrusive formations. Our results contribute thus to increasing knowledge about individual reactions to major disasters, providing information relevant to understanding the current public health crisis. Both during and after the pandemic, strategic measures that take psychological well-being into account must be implemented. Our study is finally intended to support the development of targeted interventions and strategies for the general public by examining the role of COVID-related post-emotional processes on psychological wellbeing.

Author Contributions
The authors contributed equally to this manuscript.

Compliance with Ethical Standards

Conflict of interest
The authors declare that they have no competing interests.

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