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Prosocial behaviour reduces unwanted intrusions of experimental traumatic memories

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ABSTRACT

Following trauma exposure, people often experience involuntary intrusions of traumatic memories, i.e., flashbacks. How to reduce such unwanted intrusions attracts attention from basic and translational memory research, with a goal to safeguard mental well-being and promote resilience. Here, based on prosocial behaviour's well-documented psychological benefits, we hypothesized that post-trauma prosocial behaviour would causally reduce trauma-related symptoms, including involuntary intrusions. To test this novel hypothesis, we conducted two pre-registered lab studies ($N = 180$) using trauma films to induce lab-analogue trauma exposure. Following trauma exposure, participants were randomly assigned to prosocial or non-prosocial conditions. Specifically, in the prosocial condition, participants donated money to their preferred charities. In the non-prosocial conditions, participants completed either a neutral, number judgement task (Experiment 1) or a proself task (Experiment 2). Participants completed a 1-week intrusion diary and Impact of Event Scale-Revised (IES-R), to assess frequencies of traumatic intrusions and post-trauma stress disorder symptoms, respectively. Results showed that compared to non-prosocial behaviour, prosocial engagement (i.e. performing charitable donations) reduced involuntary traumatic intrusions in both lab settings and in their daily life as evidenced by 1-week intrusion diaries. While exploratory mediation analyses suggested that intrusion reduction was partly driven by enhanced positive affect afforded by prosocial behaviour, future studies are required to illuminate the underlying mechanisms. To the extent that post-trauma prosociality alleviated trauma-related symptoms, future research is warranted to investigate how various forms of prosocial behaviour in naturalistic setting could promote resilience following trauma exposure.

"*All I knew was we had to help … how could we not help?*"

- Naoyuki Ogata, a survivor from the 1995 Tokyo sarin gas attack (Murakami, 2010)

"*I feel obligated to help now that I am on the other side of it?*"

- Andrew Sherman, COVID-19 survivor (Marcus, 2020)

Across different cultural contexts, similar anecdotes suggest that people strive to help others even under life-and-death circumstances, e.g. natural disasters, terrorist attacks, a global pandemic, etc. Echoing these anecdotes, research shows that people were more likely to engage in prosocial behaviour such as helping and volunteering if they reported experiencing more traumas (Frazier et al., 2013). Importantly, this same study suggests that among those who recently experienced traumas, prosocial behaviour enhanced positive affect and perceived meaningfulness (Frazier et al., 2013). These correlational findings raise an intriguing, yet untested, possibility that prosocial behaviour post-trauma may have therapeutic benefits in alleviating trauma-related symptoms. The current research aimed to ask: whether post-trauma prosocial behaviour would causally ameliorate trauma-related symptoms that bear clinical implications, such as involuntary intrusions of traumatic memories.

Prosocial behaviour can bring a host of psychological benefits. For example, prosocial spending (i.e., spending money for others rather than for oneself) has been shown to promote happiness and positive affect

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(Dunn et al., 2008), which has been replicated across multiple studies and in different cultural contexts (e.g. Aknin et al., 2013; Aknin et al., 2015; Aknin et al., 2020; for meta-analyses see,; Curry et al., 2018; Hui et al., 2020). In addition to positive affect, prosocial behaviour enhances ones' self-esteem, perceived meaning in life, and is considered to satisfy people's basic psychological needs such as social connectedness, autonomy, competence, and self-efficacy (e.g. Alessandri et al., 2009; Klein, 2017; Nelson et al., 2016; Weinstein & Ryan, 2010). Benefits of prosocial behaviour have also been linked with physiological and neural activities. For example, giving emotional support to friends or prosocial spending reduced participants' sympathetic nervous responses such as blood pressure and alpha-amylase (Inagaki & Eisenberger, 2016; Whillans et al., 2016). Moreover, performing prosocial charity donation elicited higher neural activity in brain regions implicated in reward and subjective valuation (e.g., the ventral striatum, the ventromedial prefrontal cortex), which was associated with enhanced self-reported positive affect and meaningfulness (e.g. Hare et al., 2010; Moll et al., 2006; Wang et al., 2020). Prosocial behaviour also has important health-related benefits: frequencies of helping and volunteering have been reliably associated with reduced risks of cardiovascular disease and even mortality risks (Brown et al., 2003; Burr et al., 2018; Okun et al., 2013).

Building on findings demonstrating prosocial behaviour's emotional and health benefits, we hypothesized that prosocial behaviour can counteract traumatic events' adverse impact and alleviate trauma-related symptoms. Specifically, we focused on involuntary intrusions of traumatic memories, which constitute one of the core symptoms for post-traumatic stress disorder (PTSD; American Psychiatric Association, 2013). Unwanted traumatic intrusions are highly vivid, distressing mental images from the traumatic experiences that would involuntarily intrude into mnemonic awareness, and would perpetuate trauma-related symptoms such as avoidance and hyperarousal (e.g. Brewin & Holmes, 2003; Ehlers et al., 2004; Holmes et al., 2004; Iyadurai et al., 2019). Therefore, one central goal of trauma memory research is to reduce unwanted involuntary intrusions (e.g. Brewin et al., 2010; Ehlers et al., 2004; Holmes et al., 2004; James et al., 2015; Lau-Zhu et al., 2019; Zeng et al., 2021). While prosocial behaviour's emotional benefits were well-established (Curry et al., 2018; Hui et al., 2020), it remains unknown whether post-trauma prosocial acts could causally alleviate trauma-related symptoms, i.e., intrusive memories in the context of lab-alangoue trauma. Examining this question will likely make unique contributions to research on prosocial behaviour and trauma symptoms, and generate new insights on how to cope with trauma and how to promote resilience in face of an adversity.

Based on the Social Cognitive Theory of Post-Trauma Recovery, perceived self-efficacy (i.e., the ability to cope with, or a sense of control over trauma) is an important determinant for the development of post-trauma symptoms including intrusions (Benight & Bandura, 2004). Evidence from real-life traumas such as military combat (Solomon et al., 1991), natural *disasters (*Benight et al., 1999*), and terrorist attack (*Benight et al., 2000*) indicate that low level of* perceived self-efficacy is a crucial risk factor for the development and maintenance of traumatic intrusive memories (Brown et al., 2012; Ehlers & Clark, 2000; Krans et al., 2018). Furthermore, based on the Retrieval-based Feedback Loop Model on Traumatic Intrusions, emotional distress surrounding the experience of intrusions would perpetuate intrusive memories (Marks et al., 2018). On the basis of these theoretical models of PTSD and intrusions, increasing self-efficacy or decreasing the distress and negative affect following trauma may reduce traumatic intrusions (Benight & Bandura, 2004; Marks et al., 2018). Because prosocial behaviour enhances positive affect and self-efficacy, and reduces negative affect and stress (e.g. Alessandri et al., 2009; Aknin et al., 2013; Klein, 2017; Nelson et al., 2016; Raposa et al., 2016; (Varma et al.); Weinstein & Ryan, 2010), we hypothesized that induction of prosocial behaviour would serve as a strong candidate to reduce trauma intrusions in the immediate aftermath of a traumatic exposure.

We conducted two pre-registered lab experiments to test our hypotheses. An overview of the experimental procedures is presented in Fig. 1a). To induce experimental trauma exposure, we employed the trauma film paradigm that has been widely used and validated to reliably induce trauma-related symptoms (e.g., involuntary intrusions, hyperarousal, distress) in well-controlled lab-settings (for reviews see, Holmes & Bourne, 2008; James et al., 2016). The trauma film consists of video clips depicting real-life traumatic events such as natural disaster, mass shooting, self-injury, etc., (see DSM-V, American Psychiatric Association, 2013). While viewing trauma films may not match the severity of directly experiencing traumatic events by oneself, repeated indirect trauma exposure from excessive media consumption could also induce trauma-related symptoms such as heightened anxiety, hyperarousal, and intrusive re-experience (DSM-V, American Psychiatric Association, 2013; Holman et al., 2014; James et al., 2016; Silver et al., 2013). Indeed, viewing trauma films as indirect trauma exposure could elicit acute PTSD-like responses such as increased physiological arousal (Chou et al., 2014), negative mood and dissociation (Holmes & Bourne, 2008), and heightened stress and anxiety (Laposa & Rector, 2012) that are akin to actual experiences of trauma. Moreover, on a daily basis, frequencies of intrusions elicited by trauma films were strongly correlated with individuals' self-reported symptoms on the IES intrusion sub-scale (Arnaudova & Hagenaars, 2017). Compared to immersive experimental trauma exposure induced via virtual reality, viewing trauma films elicited similar degrees of negative emotional reactions and frequency of intrusive memories (Dibbets & Schulte-Ostermann, 2015). At a neural level, viewing trauma films elicits aberrant brain activation patterns that are similar to PTSD patients, including decreased functional connectivity between the amygdala and medial temporal gyrus, increased connectivity between hippocampus and precuneus (Gvozdanovic et al., 2020). Collectively, these findings suggest that the trauma film paradigm offers an experimental analogue of indirect trauma exposure that reliably and prospectively elicits unwanted intrusions and trauma-related symptoms (James et al., 2016), which allows us to test our novel hypothesis on the effect of prosocial engagement in reducing intrusive traumatic memories.

Our key experimental manipulation involved the comparison between prosocial and non-prosocial conditions: Participants in the prosocial condition performed a charity donation task in which they used an additional monetary endowment to make a real-life donation to their preferred charities; while participants in the non-prosocial control conditions either performed a neutral number judgment task (Experiment 1) or a proself task involving monetary self-gains (Experiment 2; Fig. 1b). Our primary dependent variable was the frequency of involuntary traumatic intrusions. We distinguished intrusions from constructs such as worry and rumination, by operationalizing intrusive memories as vivid scenes/images from the trauma film (e.g. "I saw a car crashing into a truck") that involuntarily intrude into participants' mind in the absence of deliberate recall (James et al., 2015). In contrast, post-trauma rumination involves repetitive evaluative thoughts about the trauma and its consequences (e.g. "Why did I end up being the victim?" Arendt et al., 2021; Speckens et al., 2007).

To measure involuntary intrusions during daily life, participants recorded intrusive memories using pen-and-pencil intrusion diaries for one week (used in both Experiment 1 & 2). We used the intrusion diary because of its high ecological validity compared to retrospective questionnaires or lab-based tasks: participants would record an intrusion in real-time whenever they experience in their daily lives (e.g. Holmes et al., 2004; James et al., 2015). Frequencies of intrusions noted in the intrusion diary highly correlate with intrusion-related PTSD symptoms measured via IES (Arnaudova & Hagenaars, 2017) or the revised version of IES (IES-R) among individuals who were recently exposed to a real-life trauma (e.g. a motor accident; Iyadurai et al., 2018), as well as among PTSD patients (Kessler et al., 2018). While explicit instructions about recording intrusions may underestimate self-report of intrusion frequency in lab-based tasks given people may lack awareness of their

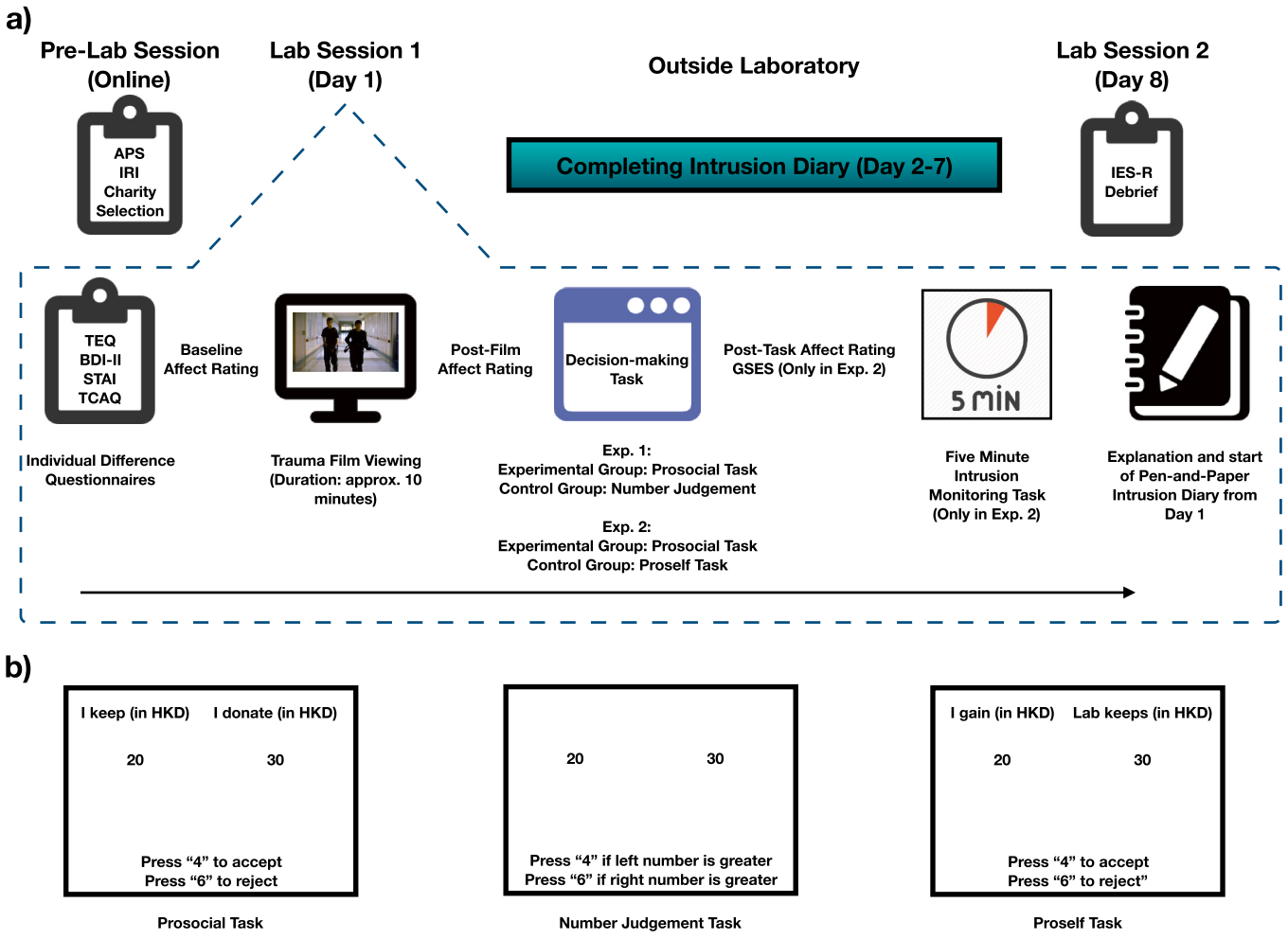

Fig. 1. **(a)** An overview of experimental procedures and tasks. In Experiment 1, participants performed either a prosocial donation task or a number judgement task. In Experiment 2, participants performed either the prosocial donation task or a proself windfall gain task. **(b)** Screenshots of decision making tasks. Response keys were counterbalanced across participants.

intrusive thoughts (Takarangi et al., 2014), it remains unknown whether explicit instructions would influence diary-based intrusions (James et al., 2016). To overcome the limitation of employing a single measurement task and to provide convergent measurement of intrusive memories (James et al., 2016), we additionally used a lab-based intrusion monitoring task in Experiment 2 (e.g. Hawkins & Cougle, 2013; Krans et al., 2013; Takarangi et al., 2014), and the IES-R referring to the trauma films in both experiments (James et al., 2015).

We preregistered the sample sizes, experimental protocol and analyses plan (https://osf.io/qp69x and https://osf.io/v4bt5). Data, materials, and analysis codes are available at https://osf.io/jvf5a/.

1. Experiment 1

1.1. Methods

Participants. Ninety non-smoking adults (71 females; mean age 22.31, range 18–49) were recruited from the University of Hong Kong. This sample size was based on *a priori* power analysis (G-Power 3.1; Faul et al., 2009) to detect Cohen's $d = 0.60$ with 80% power at a 5% false positive rate on the effect of prosocial vs. non-prosocial behaviour on trauma intrusion frequency. While no previous study had explored the causal link between prosocial behaviour and trauma intrusions, we used this effect size based on studies that employed lab-based prosocial tasks to examine prosocial behaviour's emotional benefits (e.g. prosocial spending in Dunn et al., 2008; charity donation game in Martela & Ryan, 2016). Our sample size was also informed by studies that used the trauma film and intrusion diary methods, which typically recruited 17–39 participants per condition (e.g. Holmes et al., 2004; James et al., 2015; Krans et al., 2018; Lau-Zhu et al., 2019). Participants were screened for chronic medical or psychiatric conditions. Twenty-three additional participants were excluded based on preregistered (e.g., did not return their diaries) and post-hoc defined (e.g., did not watch the entire film) exclusion criteria (for details, see supplementary online materials, SOM). Participants were randomly assigned to either the prosocial condition ($n = 45$; 33 females; Age Mean = 23.0) or the number judgement condition ($n = 45$; 38 females; Age Mean = 21.5). Participants were reimbursed 150 HKD (~19 USD) on the final day of the experiment. None of the participants had previously participated in trauma film research. They provided both online and written consents prior to the experiment. This research was approved by the Human Research Ethics Committee at The University of Hong Kong.

Materials and Procedure. The experiment involved two lab sessions (Fig. 1a). Prior to the first lab session, participants completed an online pre-screening session, in which they reported 1) prosocial tendencies on Adult Prosocialness Scale (American Psychiatric Association, 2013; Caprara et al., 2005), 2) dispositional empathy on Interpersonal Reactivity Index (IRI; Davis, 1983), and 3) demographic information. They also ranked their preferences of four local charities (recipients including children, elderly, animals) and provided explanations for their choices of the most favourite charity (see SOM).

In the first lab session on Day 1 (approx. 90 min), participants

reported 1) prior trauma experiences on an adapted version of the Traumatic Experiences Questionnaire (TEQ; James et al., 2015), 2) depression level on BDI-II (Beck et al., 1996), 3) anxiety level on the state subscale of STAI (Spielberger et al., 1983) and 4) thought control ability on the Thought Control Ability Questionnaire (TCAQ; Luciano et al., 2005). Participants then reported their positive and negative affect using an 11-point visual analogue scale (VAS) in which positive affect items (Inspired, Proud, Relaxed, Enthusiastic, Content, Happy, Pleased, Enjoyment) were adapted from PANAS (Watson et al., 1988) and negative affect items (Sad, Hopeless, Fearful, Horrified, Anxious, Depressed, Distressed) from a previous study that employed a similar trauma film paradigm (James et al., 2015). Participants were next given detailed verbal instructions regarding the following film viewing task, during which they sat alone in a darkened room at approximately 70 cm away from a monitor. Participants watched a 10-min compilation of video clips depicting traumatic scenes such as self-harm, school shooting, motor accident, surgical procedure etc. Based on past trauma film studies (e.g. James et al., 2015), the order of the trauma film clips in the film viewing task was not randomized. Participants' facial expression and adherence to watching the entire trauma film was monitored through a webcam. Audio was played through on-ear headphones. All included participants ($n = 45$) viewed the entire trauma film. After viewing the trauma film, participants reported their current positive and negative affect for a second time on the VAS (i.e., post-trauma).

Following the trauma film and VAS ratings, participants in the prosocial condition completed the charitable donation task while participants in the control condition completed the number judgement task (details below). After completing the task, participants reported their current positive and negative affect on VAS (i.e., post-task). Participants then kept their eyes closed for 5 min. After 5 min, they were provided with detailed instructions about the nature of traumatic intrusions (see SOM), and were asked whether they had experienced any intrusions during the 5 min. Verbal report was recorded but not analysed. Participants were then provided instructions on how to record their traumatic intrusions on the intrusion diaries, with their understanding of the instructions checked using an oral checklist. Participants were reminded to bring the completed diaries after one week.

In the second lab session on Day 8, participants returned their diaries. The experimenter checked their records and sought clarification wherever needed, e.g. if participants' handwriting was not clear. Participants then reported their PTSD-like symptoms on the IES-R and how accurately they completed the diary on a scale from 1 (not at all accurately) to 10 (extremely accurately). Finally, participants were debriefed and reimbursed.

Prosocial vs. Number Judgment tasks. The prosocial task was adapted from previous similar studies (e.g. Moll et al., 2006), in which participants made real monetary donations to their preferred charity. Before the task, participants were informed by the experimenter that *you will engage in a charitable donation task in which you can donate actual money to your preferred charity which you chose prior to the start of the experiment* (see SOM for task instructions presented verbally and on the computer during the prosocial task). Participants were instructed that the donation task measured their willingness to donate and that they would not gain additional money for themselves regardless of their decisions. Sixty trials were presented to the participants, with different endowment being presented in each trial. Each trial started with a fixation cross (1 s), followed by the donation offers containing two numbers side-by-side: the left-side number was the donation amount that participants could donate, the right-side number indicated the leftover money for the participant after the donation. Note that the right-side number was merely shown as a reference point to simulate a real-life donation scenario. Therefore, participants' decision to accept or reject a donation offer did not yield in any form of monetary self-gain. Participants made an *Accept* vs. *Reject* decision using *4* and *6* numerical keys with the key assignments counterbalanced across participants. If the participant chose *Accept*, they donated the amount of money presented on the left-side; if participants chose *Reject*, they chose not to donate any money, and the total amount of money in that trial was left unused. Participants were given at least 1 s to make their responses using the keys. If participants responded earlier than 1 s, a reminder "too fast" would be presented for 5 s prompting participants to respond slower. Participants were told that the final amount they donate would equal the mean donated amount from six randomly selected trials which will be multiplied by 0.4 and rounded off to the nearest 10. None of the participants rejected all donation trials. Across all 45 participants included in the final analyses, participants accepted 63.8% of the donation trials to make a charitable donation. At the end of the donation task, all participants were told that they donated 40 HKD to avoid any influence of different donation amounts on our outcome variables. Participants then signed a donation form as a record of their donation. Participants were debriefed about this fixed donation amount on Day 8.

In the control condition, participants performed a number judgement task involving the same 60 trials from the prosocial donation task. Participants were instructed that they needed to determine which of the two numbers in each pair was numerically larger by pressing "4" (for the left-side number) or "6" (for the right-side number) keys. The response keys were not counterbalanced. Trial structures were the same as in the prosocial donation task. No feedback was provided in the task. Both the tasks were programmed and run on *E-Prime* 3.0. All trials were presented in white font against a black background.

Preregistered Analysis Plan: Alpha level of 0.05 was set for all statistical comparisons. Statistical analyses were performed on *jamovi* 0.9 and *R*. Given our directional hypothesis, we preregistered to conduct one-tailed tests for between-group comparisons on our primary dependent variable: intrusive memories. All other tests were two-tailed.

Affect change. Mean positive and negative affect scores were calculated for each participant. We planned to conduct two 2 (condition: prosocial vs. number judgement, between-subject) by 3 (time: baseline vs. post-trauma vs. post-task, within-subject) mixed-design ANOVAs on positive and negative affect respectively. Wilks' lambda was used to compute the ANOVA and Greenhouse-Geisser corrections were performed to test if sphericity assumptions were violated. Bonferroni-adjusted post-hoc *t*-tests were performed to follow up significant main and interaction effects. For non-significant effect, we conducted non-preregistered follow-up *t*-tests or Mann-Whitney *U* tests (if data violated the normality assumption) to report between-group differences.

Intrusion Diaries. For each participant, we calculated 1) the total number of intrusive memories from the seven-day diaries and 2) the average emotional distress accompanying each intrusion (sum of emotional distress divided by total number of intrusions).

Because intrusive memories may not follow normal distributions, we preregistered parametric *t*-tests (if data followed normal distribution) and non-parametric Mann-Whitney *U* tests (if data violated normality assumption) to analyse intrusions. For emotional distress, we preregistered to conduct two-tailed independent sample *t*-tests. However, given that emotional distress ratings violated the normality assumption, we performed non-preregistered Mann-Whitney *U* tests.

IES-R scores. We planned to conduct two-tailed independent samples *t*-tests on participants' mean scores from the three subscales of IES-R. Given that the IES-R scores violated the normality assumptions, we also performed non-preregistered Mann-Whitney *U* tests.

Individual difference variables. Two-tailed independent samples *t*-tests were performed to test between-group differences on the APS, IRI subscales, TEQ, BDI-II, and the state subscale of STAI. We planned to conduct Pearson and Spearman rank correlational analyses among scores from APS (prosocial tendencies) IRI subscales (dispositional empathy), TCAQ (thought control ability), BDI-II (depression symptoms), STAI (anxiety levels), and the total number of intrusions from the diaries. We also planned to conduct multiple linear regression analyses, using the abovementioned scores to predict traumatic intrusions.

Non-preregistered Analysis Plan: We conducted a series of *t*-tests or the non-parametric equivalent tests on the intrusion diaries' data to

examine between-group differences on day-to-day intrusions and emotional distress. We also fit a linear mixed effects model with day-to-day intrusion frequency as the outcome variable, with fixed effects of the condition (prosocial vs. number judgement), days (Day 1, Day 2 … Day 7) and their two-way interaction. For the mixed effects model, we employed a restricted maximum likelihood (REML) structure nested within participant which included the random effect of the participant identifier. The aforesaid model with the same parameters was also applied on the outcome measure of day-to-day emotional distress.

To examine the mediating role of affect change on the influence of prosocial engagement on intrusion frequency, we ran two separate mediation analyses using the condition as the predictor and positive and negative affect change scores as mediators, respectively. Affect change scores were calculated by subtracting the post-film affect ratings from post-task affect ratings. Lastly, given our sample was largely skewed toward females (78.89% of the total sample), we conducted a series of ANCOVAs using gender as a covariate to test the between-group difference on: (i) diary-based intrusion frequency, (ii) emotional distress associated with diary-based intrusions, (iii) positive affect change scores, (iv) negative affect change scores.

1.2. Results

Descriptive (means and 95% confidence intervals calculated from 1000 bootstrapped samples) of primary outcome measures are presented in Table 1. We report results from non-parametric Mann-Whitney *U* tests when data do not follow normal distributions. *P*-values from follow-up tests are reported with Bonferroni corrections. Effect sizes for between-group comparisons are presented in Cohen's *d* using means and S.D.s from the two conditions.

1.2.1. Preregistered analyses

Diary-based traumatic intrusions and emotional distress. In total, participants across the two conditions reported 400 intrusions. Majority of the intrusions were elicited by the self-harm clip (35.5% or 142 intrusions; e.g. "A man was shaving face with razor and full of blood"), surgical procedure clip (19.25% or 77 intrusions; e.g. "The knife cut the eye membrane and make eye surgery"), and elephant rampage clip (17.5% or 70 intrusions; e.g. "I saw the image of the elephant being shot down suddenly in my mind"). Because frequencies of traumatic intrusions (Shapiro-Wilk test, W = 0.931, $p < .001$) and the emotional distress ratings (W = 0.961, $p = .009$) violated the normality assumption, we conducted Mann-Whitney *U* tests. We found that participants in the prosocial condition reported significantly fewer intrusions during the 1-week period ($M = 3.53$, SD = 3.42) compared to the number judgement condition ($M = 5.36$, SD = 3.30), $W = 650$, $p = .002$, $d = 0.54$, one-tailed (Fig. 2a). Regarding emotional distress accompanying intrusions, we did not find a significant difference between the conditions (prosocial: $M = 2.83$, SD = 2.39; number judgment: $M = 3.64$, SD = 1.96, $W = 901$, $p = .368$, $d = 0.21$ (Fig. 2c).

Affect changes. A 2 (prosocial vs. number judgement, between-subject) by 3 (baseline vs. post-trauma vs. post-task, within-subject) mixed ANOVA on positive affect ratings revealed a main effect of condition, $F(1,88) = 9.14$, $p = .003$, $\eta_p^2 = 0.094$, and time, $F(2,176) = 178.7$, $p < .001$, $\eta_p^2 = 0.67$. These two main effects were qualified by a significant condition by time interaction, $F(2,176) = 28.7$, $p < .001$, $\eta_p^2 = 0.246$. Post-hoc comparisons using Bonferroni-correction revealed that positive affect was significantly reduced from baseline to post-trauma for both conditions, $t(176) = 18.55$, $p_{Bonferroni} < .001$, $d = 1.92$ confirming trauma film's role as a stress inducer (Fig. 2e). Examining positive affect at different time points suggested that positive affect did not differ between conditions at baseline ($t(161) = 1.245$, $p_{Bonferroni} = 1.0$, $d = 0.26$) nor at post-trauma ($t(161) = 0.145$, $p_{Bonferroni} = 1.0$, $d = 0.04$). However, participants from the prosocial condition reported significantly higher positive affect ($M = 4.88$, SD = 1.69) than the control condition after the decision-making task ($M = 2.38$, SD = 1.81), $t(161) = 6.545$, $p_{Bonferroni} < .001$, $d = 1.27$.

The same 2 by 3 mixed ANOVA on negative affect rating revealed a significant main effect of condition, $F(1,88) = 5.35$, $p = .023$, $\eta_p^2 = 0.057$, time $F(2,176) = 112.94$, $p < .001$, $\eta_p^2 = 0.562$, but there was no significant condition by time interaction, $F(2,176) = 1.33$, $p = .268$, $\eta_p^2 = 0.015$. Post-hoc Bonferroni-corrected comparisons showed that viewing trauma film significantly increased negative affect in both conditions from baseline to post-trauma, $t(176) = 14.34$, $p_{Bonferroni} < .001$, $d = 1.61$ Fig. 2f). Although the condition by time interaction on negative affect was not significant, we nevertheless examined between-group differences at the three timepoints. Non-preregistered Mann-Whitney *U* tests (as data violated the normality assumption) showed that participants from the two conditions did not differ in their negative affect at baseline, $W = 1004$, $p = .945$, $d = 0.22$, and at post-film, $W = 828$, $p = .137$, $d = 0.34$. However, following the decision-making task, participants from the prosocial condition reported lower negative affect ($M = 1.14$, SD = 1.31) than the number judgement control condition ($M = 1.86$, SD = 1.88), $W = 710$, $p = .015$, $d = 0.58$.

IES-R scores and individual difference variables as predictors of traumatic intrusions. Consistent with the diary-based intrusions, participants in the prosocial condition reported significantly lower scores on the intrusion subscale of IES-R ($M = 0.50$, SD = 0.45) than the number judgment condition ($M = 0.75$, SD = 0.45), $W = 760$, $p = .041$, $d = 0.40$. No significant differences were found on the hyperarousal; $W = 870$, $p = .222$, $d = 0.30$) and avoidance $W = 843$, $p = .172$, $d = 0.28$, (Fig. S1; Table 1).

Participants' scores on individual difference questionnaires were not significantly different between the two conditions (see SOM; Table S1). None of the individual difference measures were significant predictors of, nor correlated with the frequencies of intrusive memories. Moreover, participants' proportion of prosocial choices (i.e. number of accepted trials divided by number of total trials) were not significantly correlated with their trauma intrusion frequency ($r = 0.04$, $p = .80$).

1.2.2. Non-preregistered analyses

Day-to-day diary-based traumatic intrusions and emotional distress. A series of Mann-Whitney *U* tests revealed that the impact of prosocial engagement was most evident in the early aftermath of trauma

Table 1
Descriptive of outcome measurements, Mean and 95% C·I.s based on 1000 bootstrapped samples.

	Experiment 1		Experiment 2	
Outcome measurements	Prosocial	Number Judgement	Prosocial	Proself
Traumatic intrusions (diary)	3.53 [2.67, 4.67]	5.36 [4.45, 6.29]	4.04 [3.06, 5.19]	5.98 [4.60, 7.58]
Emotion Distress	3.18 [2.43, 3.81]	3.64 [3.04, 4.14]	3.31 [2.69, 4.13]	4.08 [3.39, 4.68]
Traumatic Intrusions (lab)			3.23 [2.51, 4.24]	4.83 [3.93, 5.88]
Self-efficacy			3.68 [3.49, 3.82]	3.81 [3.66, 3.96]
Intrusion (IES-R)	0.59 [0.48, 0.73]	0.78 [0.65, 0.91]	0.68 [0.57, 0.82]	0.95 [0.76, 1.17]
Avoidance (IES-R)	0.91 [0.72, 1.12]	1.10 [0.90, 1.28]	1.08 [0.88, 1.27]	1.06 [0.84, 1.29]
Hyperarousal (IES-R)	0.17 [0.11, 0.26]	0.26 [0.17, 0.36]	0.27 [0.17, 0.46]	0.24 [0.15, 0.41]

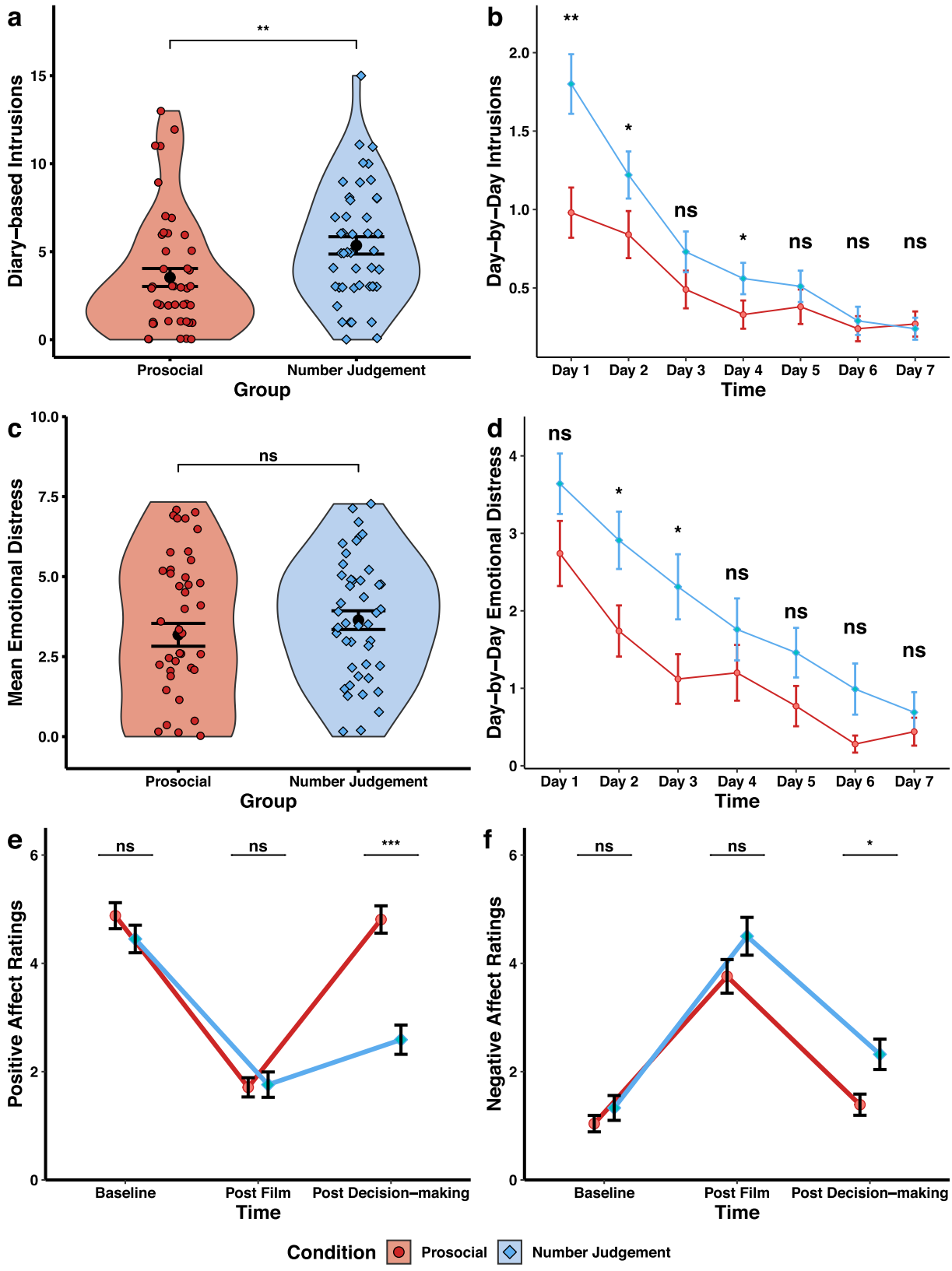

Fig. 2. Results of Experiment 1: **(a)** over 7 days, participants in the prosocial group reported fewer number of involuntary intrusions than the control group **(b)** the effect was most evident in the first two days based on exploratory, day-to-day analyses; **(c)** mean subjective emotional distress accompanying each intrusion did not differ between the two conditions and **(d)** day-to-day mean subjective emotional distress. Affect changes across baseline, post-film and post-task in the two groups: **(e)** positive affect change. Prosocial behaviour increased positive affect than the number judgment task. **(f)** negative affect change. Error bars indicates S.E.

exposure on Days 1, 2 and 4 ($W = 622$, $p < .001$, $d = 0.69$, $W = 771$, $p = .020$, $d = 0.38$, $W = 825$, $p = .037$, $d = 0.34$; Fig. 2b). Participants from the prosocial condition also reported significantly lower emotional distress than the number judgement condition on Days 2 and 3 ($W = 735$, $p = .021$, $d = 0.50$; $W = 771$, $p = .028$, $d = 0.47$; Fig. 2d).

The linear mixed effects model fit revealed a significant main effect of condition ($B = 0.26$, 95% C.I. [0.06, 0.46], $F(1,88) = 6.62$, $p = .012$, $\eta_p^2 = 0.069$) and days ($F(6,528) = 32.70$, $p < .001$, $\eta_p^2 = 0.271$). Interestingly, there was a significant condition by day interaction ($F(6,528) = 3.59$, $p = .002$, $\eta_p^2 = 0.039$). Post-hoc Bonferroni-corrected comparisons showed that the prosocial condition reported significantly lower intrusion frequency than the number judgement condition only on Day 1 ($t(454) = 4.82$, $p_{Bonferroni} < .001$, $d = 0.45$). The same mixed effects model on day-to-day emotional distress revealed a significant main effect of condition ($B = 0.78$, 95% C.I. [0.21, 1.35], $F(1,88) = 7.26$, $p = .008$, $\eta_p^2 = 0.076$) as well as days ($F(6,528) = 22.80$, $p < .001$, $\eta_p^2 = 0.271$). However, there was no significant condition by day interaction ($F(6,528) = 0.729$, $p = .626$, $\eta_p^2 = 0.008$).

Affect changes as mediators. When using condition (prosocial vs. number judgment) to predict diary-based traumatic intrusions, we found that the positive affect change scores ($\beta = 0.16$, 95% C.I. [0.04, 1.09], $p = .036$), but not negative affect changes ($\beta = 0.06$, 95% C.I. [−0.23, 0.42], $p = .569$), mediated the between-group differences in intrusion frequencies. This result suggests that positive affect enhancement afforded by prosocial behaviour significantly contributed to the observed reduction in traumatic intrusions.

Gender as a covariate for differences in intrusion frequency and affect. After controlling for gender, prosocial condition had significantly lower traumatic intrusions ($F(1,87) = 5.59$, $p = .020$, $\eta_p^2 = 0.060$) and significant positive affect enhancement ($F(1,87) = 47.17$, $p < .001$, $\eta_p^2 = 0.352$) compared to the number judgement condition. The two conditions did not significantly differ in terms of emotional distress associated with the intrusions ($p = .455$) and the negative affect change scores ($p = .594$). Therefore, including gender as a covariate did not change the aforementioned results.

1.3. Discussion

Experiment 1 provided initial evidence that engaging in prosocial donations causally reduced involuntary intrusions following experimental trauma exposure. Consistent with previous research (e.g. Dunn et al., 2008; Frazier et al., 2013; Raposa et al., 2016; Weinstein & Ryan, 2010), prosocial behaviour was associated with emotional benefits: it enhanced participants' positive affect even following highly aversive traumatic exposure. Beyond emotional benefits, participants reported fewer involuntary intrusions in the subsequent seven days. Prosocial behaviour's benefits in alleviating trauma-related symptoms were also obtained in the IES-R intrusion subscale. Importantly, the impact of prosocial behaviour on intrusive memories was mediated by positive affect changes, suggesting that positive affect enhancement could be driving the observed reduction of intrusions.

Experiment 2 served to replicate and extend Experiment 1 with the following changes. First, instead of the neutral number judgment task, participants in the control condition performed a proself windfall gain task. We hypothesized that participants may also experience positive affect as they gained money for themselves. If prosocial behaviour still led to reduced intrusive memories than proself behaviour, then affect change alone should not fully explain prosocial behaviour's benefits. To further explore the underlying mechanisms, we measured participants' perceived self-efficacy using a modified version of the General Self-Efficacy Scale (Schwarzer & Jerusalem, 1995), given previous evidence that prosocial behaviour boosted perceived competence and self-efficacy (Alessandri et al., 2009). Lastly, we used a 5-min lab-based intrusion monitoring task in addition to the 1-week intrusion diary to examine prosocial vs. proself behaviour's immediate impact on involuntary intrusions.

2. Experiment 2

2.1. Methods

Participants. Following the same sample size rationale, inclusion criteria and recruitment procedure as of Experiment 1, 90 healthy adults were recruited from the University of Hong Kong. Nineteen additional participants were excluded following the preregistered exclusion criteria, which were based on the same criteria as of Experiment 1 (see SOM). We additionally excluded one participant who correctly predicted the study hypothesis during the debriefing session (non-preregistered), to avoid any potential response bias. Ninety participants were randomly assigned to either the prosocial condition ($n = 45$, 35 females, $Mean_{age} = 20.2$) or the proself condition ($n = 45$, 37 females, $Mean_{age} = 20.1$). Participants were paid 150 HKD (~19 USD) for their participation.

Materials and procedure. The procedure was the same as in Experiment 1, except for the following: 1) participants in the control condition performed a proself windfall gain task (details below); 2) participants finished state- and trait-subscales of STAI as well as reported their perceived self-efficacy on an adapted version of the General Self-Efficacy Scale (GSES; for details, see SOM); 3) participants finished a lab-based intrusion monitoring task to measure traumatic intrusions immediately following the experimental manipulations; and 4) VAS included 6 positive affect (Inspired, Proud, Relaxed, Enthusiastic, Happy, Content) and 6 negative affect items (Sad, Hopeless, Fearful, Anxious, Depressed, Distressed).

Prosocial vs. Proself Task. The prosocial donation task was the same as in Experiment 1. Across all 45 participants included in the final analyses, participants accepted 56% of the trials to make a charitable donation. Participants in proself condition were presented with the same trials, except that their task was to gain additional money for themselves. Specifically, participants were told that *you will engage in an economic decision-making task designed to measure the amount of money people choose to keep during a windfall gain* (see SOM for task instructions). In each trial, two numbers were presented side-by-side: the left-side number was the amount of money participants could gain, the right-side number was the leftover money for the lab. Critically, the right-side number was merely provided as a reference point, which would help participants decide whether to accept their windfall gain or not. Therefore, participants' decisions in this windfall gain task would only influence their self-gain, but not any other entity (e.g., the lab). Participants made an *Accept* vs. *Reject* decision using *4* and *6* numerical keys, while key assignments were counterbalanced across participants. By accepting an offer, participants would gain the amount of money shown on the left-side (i.e., self-gain); by rejecting the offer, participants would not gain any money and the total amount of money would be left unused. Across all 45 participants included in the final analyses, participants accepted majority of the trials (66.44%) to make a self-gain. Trial structures were kept the same as in the prosocial donation task. To ensure participants' task engagement and workload were comparable between prosocial and proself tasks, participants were given the same rules as in the prosocial task: the final amount would equal the averaged amount from six randomly selected trials, multiplying by 0.4 and rounding off to the nearest 10. No participants rejected all proself trials. At the end of the proself task, participants were all given 40 HKD, the same amount as the donated amount in the prosocial task. Participants were debriefed about this fixed amount on Day 8. Both tasks were programmed and run on *PsychoPy* 3.0. All trials were presented in white font against a grey background.

Intrusion Monitoring Task: Participants were given detailed instructions on the nature of involuntary intrusions. They then kept their eyes closed for 5 min, and would press the *Spacebar* on the keyboard every time they experienced an involuntary intrusion from the trauma film. The task was programmed on *PsychoPy* 3.0. At the end of the task, participants verbally described the contents of intrusions and their

subjective distress level to further understand the nature of intrusions.

Preregistered Analysis Plan: Analyses would be the same as in Experiment 1, except for the following:

Affect change. We preregistered follow-up independent samples *t*-tests for pairwise comparisons. Non-preregistered Mann-Whitney *U* tests were conducted if data violated the normality assumption.

Emotional distress. We preregistered both parametric independent samples *t*-tests and non-parametric Mann-Whitney *U* tests in case the data were not normally distributed.

Intrusion monitoring task. We counted how many times participants hit the spacebar during the 5-min eyes-closed periods. We used both parametric independent samples *t*-test and its non-parametric equivalent Mann-Whitney *U* test to analyze between-group differences in intrusions. As in Experiment 1, we used one-tailed tests for between-group comparisons of intrusive memories.

Self-efficacy on GSES. We planned to conduct a two-tailed independent samples *t*-test or its non-parametric equivalent (if data violated the normality assumption) to test between-group differences in self-efficacy scores.

Day-to-day traumatic intrusions and associated emotional distress. Multiple one-tailed independent samples *t*-tests (or its non-parametric equivalent *U*-tests) were conducted to test between-group differences in frequencies of traumatic intrusions on each of the seven days. Two-tailed *t*-tests or its non-parametric equivalents were conducted for mean emotional distress accompanying each intrusion on each of the seven days in the intrusion diary.

Non-preregistered Analysis Plan: As in Experiment 1, we conducted the same linear mixed effects models (REML fit) on diary-based day-to-day intrusion frequency and the day-to-day emotional distress. Both models included fixed effects of the condition (Prosocial vs. Proself), Days (Day 1, Day 2 … Day 7) and their two-way interaction, and the random effects of individual participant.

The mediating role of affect change on the effect of prosocial behaviour on lab-based and diary-based intrusions was tested via a series of mediation analyses using the condition as the predictor and positive and negative affect change scores as mediators. Affect change scores were calculated by subtracting the post-film affect ratings from post-task affect ratings. Since our sample was skewed toward females (77.78% of the total sample) in Experiment 2 as well, we conducted a series of ANCOVAs using gender as a covariate to test for between group difference on: (i) diary-based intrusion frequency, (ii) lab-based intrusions, (iii) emotional distress associated with diary-based intrusions, (iv) positive affect change scores, (v) negative affect change scores.

2.2. Results

Descriptive (means and 95% confidence intervals calculated from 1000 bootstrapped samples) are presented in Table 1.

2.2.1. Preregistered analyses

Diary-based traumatic intrusions and emotional distress. In total, participants across the two conditions reported 451 intrusions. Majority of the intrusions were elicited by the self-harm clip (38.14% or 172 intrusions; e.g. "I saw the man with the shaver as the first drop of blood flows down his chest"), surgical procedure clip (19.5% or 88 intrusions; e.g. "I saw a scalpel peeling off a slice from an eyeball"), and school shooting clip (15.5% or 70 intrusions; e.g. "A student is shot down in classroom"). Similar to Experiment 1, we reported results from Mann-Whitney *U* tests because the frequency of traumatic intrusions ($W = 0.906$, $p < .001$) and emotional distress ratings ($W = 0.958$, $p = .006$) violated the normality assumption. Again, participants in the prosocial condition reported fewer intrusions ($M = 4.04$, SD = 3.69) than the proself condition ($M = 5.98$, SD = 5.19), $W = 801$, $p = .044$, $d = 0.43$, one-tailed (Fig. 3a). Participants in the prosocial condition also reported lower emotional distress ($M = 3.31$, SD = 2.39) than proself condition ($M = 4.08$, SD = 2.12), although this difference was not significant, $W = 814$, $p = .110$, $d = 0.34$ (Fig. 3c). Moreover, participants' proportion of prosocial and proself choices (i.e. number of accepted trials divided by number of total trials) were not significantly correlated with their trauma intrusion frequency (Prosocial: $r = -0.20$, $p = .19$; Proself: $r = -0.25$, $p = .11$).

We next examined day-to-day between-group differences. We found significant differences between the prosocial and proself conditions on Day 1 and Day 4 ($W = 804$, $p = .040$, $d = 0.41$; $W = 770$, $p = .013$, $d = 0.37$; Fig. 3b). Participants in the prosocial condition also reported significantly lower emotional distress than the proself condition on Day 4 ($W = 740$, $p = .012$, $d = 0.48$; Fig. 3d). No other results were significant.

Lab-based traumatic intrusions. Adopting the same criterion as the diary-based intrusions, participants were excluded if their intrusions were beyond 3 S.D.s of the condition's mean ($n = 2$ from the prosocial condition, $n = 4$ from the proself condition). Because distributions of intrusive memories violated the normality assumption (Shapiro-Wilk test W = 0.952, $p < .001$), we conducted the non-parametric Mann-Whitney *U* test. Results showed that prosocial behaviour significantly reduced involuntary traumatic intrusions ($M = 3.23$, SD = 2.81) than proself behaviour ($M = 4.83$, SD = 3.24), $W = 616$, $p = .008$, $d = 0.53$, one-tailed (Fig. 4). Thus, consistent with diary-based results, performing prosocial charity donation had immediate beneficial effects in reducing involuntary intrusions.

Affect changes. The same 2 by 3 mixed ANOVA on positive affect ratings revealed a significant time effect, $F(2,176) = 163.30$, $p < .001$, $\eta_p^2 = 0.65$. The condition effect was not significant, $F(1,88) = 0.42$, $p = .52$, $\eta_p^2 = 0.005$. The condition by time interaction was also not significant, $F(2,176) = 2.44$, $p = .090$, $\eta_p^2 = 0.007$. Following up the significant time effect, paired-sample *t*-tests with Bonferroni-corrections showed that positive affect significantly declined for both conditions from baseline to post-trauma, $t(176) = 16.76$, $p_{Bonferroni} < .001$, $d = 1.63$, again confirming trauma film's effectiveness in reducing positive affect (Fig. 3e). Moreover, participants from both conditions reported elevated positive affect from post-trauma to post-task, $t(176) = 14.24$, $p_{Bonferroni} < .001$, $d = 1.28$. When comparing participants' positive affect between Prosocial ($M = 4.83$, SD = 1.79) and Proself condition at post-task ($M = 4.50$, SD = 2.14), participants reported similar levels of positive affect, $t(88) = 0.48$, $p = .632$, $d = 0.10$ (Fig. 3e).

The same 2 by 3 mixed design ANOVA on negative affect ratings similarly revealed a significant time effect, $F(2,176) = 97.76$, $p < .001$, $\eta_p^2 = 0.526$. The condition effect was not significant: $F(1,88) = 1.06$, $p = .305$, $\eta_p^2 = 0.012$. The condition by time interaction was not significant, $F(2,176) = 0.565$, $p = .569$, $\eta_p^2 = 0.006$. Following up the significant time effect, paired-sample *t*-tests with Bonferroni-corrections showed that in both conditions, negative affect increased from baseline to post-trauma, $t(176) = 11.84$, $p_{Bonferroni} < .001$, $d = 1.06$, and it decreased from post-trauma to post-task: $t(176) = 12.359$, $p_{Bonferroni} < .001$, $d = 1.17$. prosocial ($M = 1.33$, SD = 1.55) and proself conditions reported similar levels of negative affect at post-task ($M = 1.83$, SD = 1.49), $W = 937$, $p = .544$, $d = 0.12$ (Fig. 3f).

Self-efficacy. Self-efficacy did not differ between prosocial and proself conditions, $t(88) = 1.17$, $p = .245$, $d = 0.25$ (Table 1).

IES-R. We did not find significant differences between the prosocial and the proself conditions in any of the three subscales of IES-R (for descriptive, see Table 1): on the intrusion subscale, $W = 830$, $p = .140$, $d = 0.47$, on the avoidance subscale, $W = 963$, $p = .692$, $d = 0.02$, and on the hyperarousal scale, $W = 962$, $p = .660$, $d = 0.07$.

Individual difference variables as predictors of traumatic intrusions Participants' scores on individual difference variables were not significantly different between the two conditions (see SOM; Table S2). Regression analyses using individual difference measures to predict traumatic intrusions showed that in the proself condition, participants' empathetic concern ($\beta = 0.52$, $p = .017$, 95% C.I. [0.10, 0.93]) from the IRI was a significant predictor for their diary-based intrusions (Table 2). When the data were collapsed across the two conditions, we found that

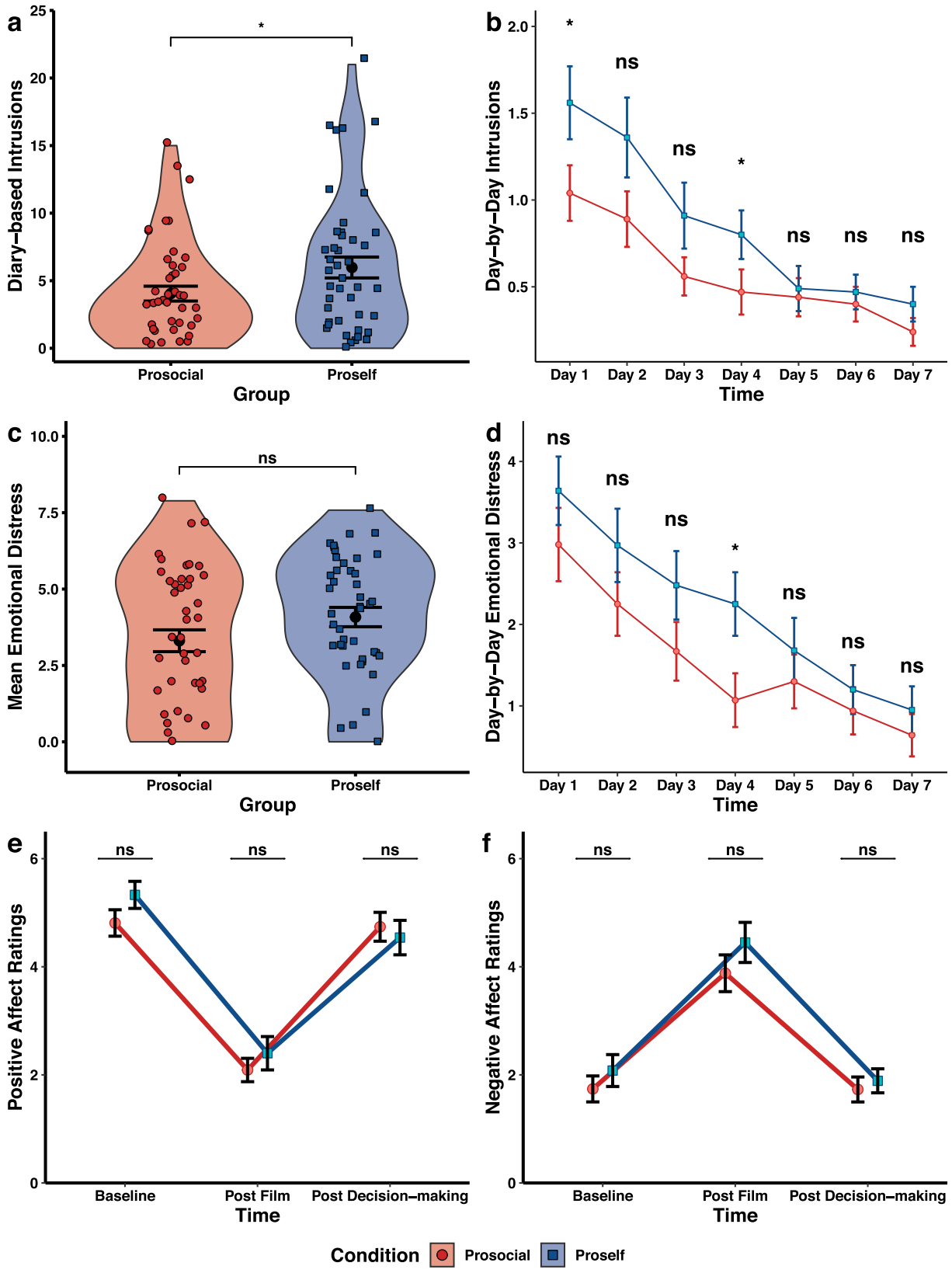

Fig. 3. Results of Experiment 2: **(a)** participants in the prosocial group reported fewer number of involuntary intrusions than the proself control group. **(b)** the differences were most evident in the early aftermath of experimental trauma based on day-to-day analyses; **(c)** mean subjective emotional distress accompanying each intrusion and **(d)** mean subjective emotional distress on Day 1 to Day 7. Affect changes across baseline, post-film and post-task in the two groups: **(e)** positive affect change, **(f)** negative affect change. Error bars indicates S.E.

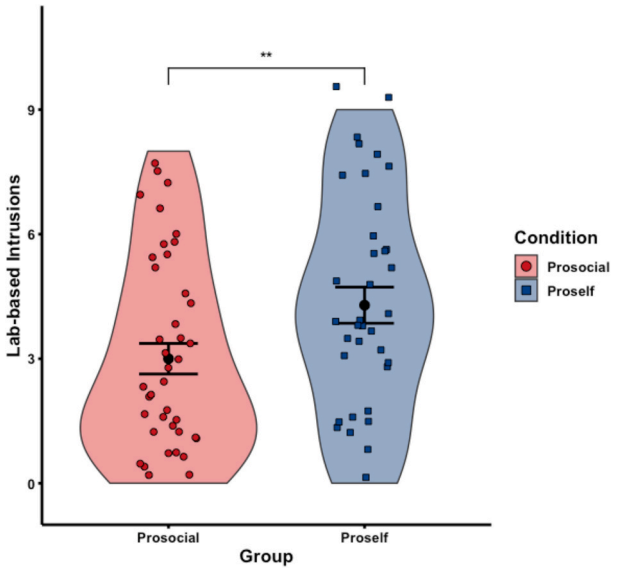

Fig. 4. Results from the 5-min lab-based intrusion monitoring task in Experiment 2. Participants in the prosocial group reported fewer number of involuntary intrusions than the proself control group. Error bars indicates S.E.

Table 2
Experiment 2 Regression results using diary-based traumatic intrusion frequency as the outcome measure in the proself condition ($n = 45$).

Predictor	*b*	95% CI	*β*	95% CI
(Intercept)	0.49	[-36.78, 37.77]		
Adult Prosocialness Scale (APS)	−0.26	[-0.60, 0.08]	−0.35	[-0.81, 0.11]
Perspective Taking (IRI)	0.38	[-0.15, 0.92]	0.27	[-0.11, 0.65]
Empathetic Concern (IRI)	0.95*	[0.18, 1.72]	0.52*	[0.10, 0.93]
Personal Distress (IRI)	−0.23	[-0.75, 0.30]	−0.15	[-0.51, 0.20]
Depression Score (BDI-II)	−0.22	[-0.83, 0.39]	−0.19	[-0.72, 0.34]
State Anxiety (STAI-S)	0.04	[-0.25, 0.33]	0.07	[-0.38, 0.52]
Trait Anxiety (STAI-T)	−0.04	[-0.48, 0.41]	−0.06	[-0.81, 0.68]
Thought Control Ability (TCAQ)	−0.08	[-0.29, 0.13]	−0.21	[-0.75, 0.33]

* indicates $p < .05$.

empathetic concern was positively correlated with diary-based traumatic intrusion frequency (r (90) = 0.24, 95% C.I. [0.04, 0.43], $p = .02$).

2.2.2. Non-preregistered analyses

Day-to-day diary-based traumatic intrusions and emotional distress. To examine the interaction between conditions and day-to-day changes on intrusion frequency, we conducted a linear mixed effects model fit on the outcome measure of day-to-day intrusion frequency which revealed a significant main effect of condition ($B = 0.28$, 95% C.I. [0.01, 0.54], F (1,88) = 4.15, $p = .045$, $\eta_p^2 = 0.045$) and across all seven day-to-day difference (F (6,528) = 19.48, $p < .001$, $\eta_p^2 = 0.181$). However, there was no significant condition by day interaction (F (6,528) = 1.28, $p = .264$, $\eta_p^2 = 0.014$). The same mixed effects model fitted onto the outcome variable of day-to-day emotional distress only showed a main effect of day-to-day changes (F (6,528) = 16.11, $p < .001$, $\eta_p^2 = 0.155$).

Affect changes as mediators. To further understand the influence of affect change on intrusive memories, we conducted the same mediation analyses as in Experiment 1 on lab-based and diary-based traumatic intrusions. For lab-based intrusions, the mediation models showed that neither positive nor negative affect change scores mediate lab-based intrusions ($\beta = -0.009$, 95% C.I. [−0.26, 0.15], $p = .598$) ($\beta = 0.01$, 95% C.I. [−0.12, 0.29], $p = .415$). The same pattern of results emerged for diary-based traumatic intrusions: neither positive nor negative affect change scores mediate the diary-based intrusions ($\beta = -0.04$, 95% C.I. [−0.42, 0.09], $p = .208$) ($\beta = 0.01$, 95% C.I. [−0.09, 0.23], $p = .410$). This result suggests that in Experiment 2, affect changes alone did not account for the effect of prosocial behaviour on intrusion reduction.

Gender as a covariate for differences in intrusion frequency and affect. After controlling for gender, prosocial condition had significantly lower lab-based traumatic intrusions (F (1,87) = 6.47, $p = .013$, $\eta_p^2 = 0.069$) as well as diary-based intrusion frequency (F (1,87) = 3.98, $p = .049$, $\eta_p^2 = 0.044$) compared to the proself condition. The two conditions did not significantly differ in terms of emotional distress associated with intrusions ($p = .115$), positive ($p = .141$) and negative affect change scores ($p = .279$) after controlling for gender. Hence, including gender as a covariate did not alter the aforementioned results.

2.2.3. Pre-registered combined analyses of experiment 1 and 2

To further confirm results obtained in single experiments, and to test our hypothesis with higher statistical power, we conducted analyses based on combined samples from Experiments 1 and 2. We tested whether the three conditions, prosocial ($n = 90$), number judgement ($n = 45$), and proself ($n = 45$) differed in terms of: (1) total number of traumatic intrusions over the 1-week period and the mean emotional distress accompanying each intrusion, and (2) number of traumatic intrusions and the accompanying emotional distress on each of the seven days. Multiple one-way ANOVAs with the three conditions being the independent variable and aforementioned variables as dependent variables were performed. However, the data distribution of the aforementioned dependent variables violated the normality assumption. Therefore, we conducted Kruskal-Wallis tests (the non-parametric equivalent of one-way ANOVA) and the Dwass-Steel-Critchlow-Fligner tests to follow up significant effects. We also ran 3 (conditions, prosocial vs. number judgement vs. proself; between-subject) by 3 (time, baseline vs. post-trauma vs. post-task; within-subject) mixed ANOVAs to analyse changes in positive and negative affect ratings, respectively. If significant main effects or interaction effects were observed, we conducted follow-up *t*-tests for pairwise comparisons.

In the case of 7-day average of diary-based traumatic intrusions, there was a main effect of condition, $X^2 = 10.78$, $p = .005$, $d = 0.46$. Post-hoc pairwise comparisons showed that the prosocial condition had significantly lower number of traumatic intrusions than the number judgement ($p = .008$) as well as the proself condition ($p = .05$) while the latter two conditions did not significantly differ from each other ($p = .996$). Day-to-day analyses showed significant between-group differences on Day 1 and Day 4 (Day 1: $X^2 = 13.95$, $p < .001$, $d = 0.54$; Day 4: $X^2 = 9.31$, $p = .01$, $d = 0.42$). Post-hoc comparisons revealed that prosocial behaviour's benefits in reducing intrusions were evident on Day 1 (prosocial vs. number judgment, $p < .001$) and on Day 4 (prosocial vs. proself, $p = .01$). For the other 5 days, there was no significant main effect of condition.

In terms of the 7-day average of emotional distress associated with the diary-based traumatic intrusions, there was no significant main effect of condition, $X^2 = 4.37$, $p = .112$, $d = 0.23$. However, the average emotional distress on Day 3 and 4 was significantly different between the three conditions (Day 3: $X^2 = 6.65$, $p = .036$, $d = 0.33$; Day 4: $X^2 = 9.33$, $p = .009$, $d = 0.42$). Post hoc comparisons revealed that participants from the prosocial condition reported lower emotional distress than the proself condition (Day 4, $p = .01$). No other comparisons were significant.

We also compared affect changes between the three conditions by conducting 3 (prosocial vs. number judgement vs. proself; between-subject) x 3 (baseline vs. post-film vs. post-task; within-subject) mixed design ANOVAs on positive and negative affect ratings, separately. For

positive affect, we found a significant time effect (F (2,354) = 286.9, p < .001, η_p^2 = 0.618), condition effect (F (2,177) = 8.27, p < .001, η_p^2 = 0.086), and a condition × time interaction (F (4,354) = 15.6, p < .001, η_p^2 = 0.15). Post-hoc Bonferroni comparisons revealed the following: (1) at baseline and post-film, participants in the three conditions did not significantly differ from each other; (2) positive affect in all three conditions was significantly reduced post-film as compared to baseline; (3) after task, participants who performed prosocial behaviour experienced greater positive affect (M = 4.78, SD = 1.73) than the number judgement condition (M = 2.59, SD = 1.81), t (313) = 7.01, p < .001, d = 1.24), and proself condition (M = 4.54, SD = 2.14) also reported greater positive affect than the number judgement condition, t (313) = 5.43, p < .001, d = 0.99. Prosocial and Proself condition did not differ in terms of positive affect post decision-making task (p = 1.00). For negative affect, a significant time effect was found (F (2,354) = 192.74, p < .001, η_p^2 = 0.521) but no significant main effect of condition (F (2,177) = 2.6, p = .077, η_p^2 = 0.029). There was a significant condition by time interaction (F (4,354) = 2.72, p = .03, η_p^2 = 0.03). Similar with the case of positive affect, post-hoc Bonferroni comparisons revealed the following: (1) at baseline and post-film, participants' negative affect in the three conditions did not significantly differ from each other; (2) negative affect in all three conditions was significantly higher post-film as compared to baseline. However, after task, none of the three conditions were significantly different from each other.

2.3. Discussion

Experiment 2 offered further empirical support that after an experimental trauma exposure, prosocial engagement reduced frequency of trauma intrusions compared to proself monetary gains. Reduction in intrusion frequency was evident in the immediate lab-based intrusion monitoring task and in the one-week intrusion diaries. Hence, Experiment 2 replicated prosocial behaviour's therapeutic effect in reducing involuntary trauma intrusions as first found in Experiment 1. However, unlike Experiment 1, prosocial and proself behaviour had comparable effects on positive and negative affect changes, suggesting that emotional benefits of prosocial behaviour alone cannot explain the reduction in trauma intrusion frequency among participants from the prosocial condition.

3. General discussion

From earthquake to terrorist attacks, people who are exposed to trauma often experience involuntary flashbacks of traumatic memories that are vivid and distressful, which perpetuates development of trauma-related symptoms. How to reduce unwanted intrusions becomes an imperative question for both basic and translational memory research. Our research suggests a new, socio-emotional approach in reducing involuntary traumatic intrusions via prosocial engagement. Across two pre-registered experiments, post-trauma prosocial donations not only had instant affect benefits such as distress reduction and positive affect enhancement but brought longer term benefits in ameliorating a core symptom of trauma-related psychopathology: unwanted intrusions of traumatic memories (e.g. Ehlers et al., 2004).

The trauma film paradigm is widely used in experimental psychopathology to study traumatic reactions such as emotional distress and intrusive memories (James et al., 2016). Here, viewing trauma films successfully reduced positive affect, induced negative affect and involuntary intrusions of traumatic memories. Consistent with our pre-registered hypothesis, Experiment 1 showed that charitable donations had immediate emotional benefits: prosocial donations enhanced positive affect, reduced negative affect, and subsequently reduced trauma intrusion frequency. Experiment 2 provides further evidence that post-trauma prosocial donations (vs. proself gains) can reduce trauma intrusion frequency.

Based on linear mixed modelling to track the effect of prosocial behaviour on day-to-day intrusion frequency, we found that prosocial behaviour reduced intrusion frequency particularly during the early days (Day 1 & 2) of the 1-week intrusion diaries. Moreover, prosocial behaviour reduced intrusions in the lab-based intrusion monitoring task that was administered immediately after the prosocial manipulation. Together, these findings suggest that the benefits of prosocial behaviour in reducing intrusions are particularly evident during the early aftermath of a traumatic experience. This early reduction of intrusion frequency could be critical for long-lasting benefits to emerge across the seven-day period (e.g. Iyadurai et al., 2018; Iyadurai et al., 2019; James et al., 2015). In fact, research has found that intrusive memories immediately following the trauma is strongly linked to the development of later PTSD symptoms among patients with traumatic injuries (Bryant et al., 2017, see also; Haag et al., 2017). Therefore, early reduction of intrusive memories could be a key to prevent future PTSD diagnoses (McNally, 2017). It is also worth mentioning that we found a significant reduction of intrusion frequency on Day 4 across both experiments, suggesting benefits of prosocial behaviour may even have a longer-term effect beyond the first few days. Future research, ideally with a larger sample size, could further test whether this effect replicates.

We also found that in Experiment 2, participants' self-reported empathic concerns and their diary-based trauma intrusion frequency were positively correlated across the whole sample. Previous research reveals that people with higher emotional empathy show more biased processing of negative emotions, which may perpetuate empathic distress (Chikovani et al., 2015; Davis et al., 1987). Our findings further suggest that during trauma film watching, participants with elevated dispositional empathy may experience a higher level of concern and distress, which then contributed to higher intrusion frequencies.

Prosocial behaviour's emotional benefits as documented in Experiment 1, such as enhanced positive affect and reduced distress, may serve as a potential mechanism that drives the reduction of intrusive memories, as proposed by the Retrieval-based Feedback Loop Model (Marks et al., 2018). However, results from Experiment 2 suggested that affect change alone could not explain our findings: while both charitable donations and proself gaining had similar effects in reducing negative affect and enhancing positive affect, only prosocial behaviour reduced subsequent involuntary intrusions. Although prosocial and proself behaviours had similar affect benefits in Experiment 2, there are other important differences between these two tasks in terms of the psychological processes involved. Neuroimaging research has shown that, compared to personal gains, prosocial behaviour engaged neural circuits that are associated with mentalizing and inferring about others' mental states (e.g., the dorsomedial prefrontal cortex, the temporoparietal junction and the posterior cingulate cortex, Morelli et al., 2015). We speculate that the other-oriented cognitive processing engaged during the prosocial task may have driven intrusion reduction in the prosocial condition. Specifically, traumatic experiences could have promoted self-referential processing and egocentric thinking, which then lead to rumination over trauma memories and PTSD-related symptoms (Cooney et al., 2010; Michael et al., 2007; Sartory et al., 2013). Performing prosocial behaviour, on the other hand, could have diverted participants' attention to their preferred charities, while reducing excessive egocentric and self-referential processing. It should also be noted that mentalizing or other-oriented processing alone may not have yielded the observed benefits here. Mentalizing can have different goals: in a competitive game, participants would engage in other-oriented thinking with a goal to maximize their self-gains (Hampton et al., 2008; for review see; O'Doherty et al., 2017). It is possible that in a prosocial task, other-oriented thinking to empathize with others, together with a goal to improve others' well-being, would contribute to prosocial behaviour's therapeutic benefits in alleviating trauma-related symptoms. Future research is warranted to further test this possibility.

Another candidate mechanism for prosocial behaviour's therapeutic benefit is enhanced self-efficacy (Alessandri et al., 2009; Benight & Bandura, 2004). In Experiment 2, we explored whether prosocial

behaviour may enhance perceived self-efficacy, which then would reduce involuntary traumatic intrusions. Previous research suggests that prosocial behaviour could satisfy fundamental psychological needs such as self-worth, meaningfulness, competence etc. (e.g. Klein, 2017). However, most of these studies did not directly compare prosocial with proself behaviour in terms of self-efficacy. Here, we found that participants in the prosocial and proself conditions did not differ in their perceived self-efficacy, possibly because our adapted questionnaire was not sensitive in capturing situational changes of self-efficacy. Moreover, proself task may also have boosted participants' self-efficacy because they had gained money and experienced enhanced positive affect. Future studies should consider using more specific items (e.g., meaningfulness with direct reference to prior donations; Wang et al., 2020) to capture subtle psychological changes due to prosocial behaviour.

Related to meaningfulness, another potential mechanism may involve meaning-making uniquely afforded by post-trauma prosocial engagement (e.g. Hernández-Wolfe, 2011; Midlarsky, 1991; Vollhardt, 2009; Vollhardt & Staub, 2011). Specifically, meaning-making allows trauma-exposed individuals to incorporate the traumatic experience into one's self-view in a constructive manner, resulting in posttraumatic growth and reduction of trauma-related symptoms, including involuntary intrusions (e.g. intrusions, Vollhardt, 2009; Zoellner & Maercker, 2006). Future research should directly measure changes in meaning-making produced by prosocial behaviour within the context of trauma, to examine the psychological mechanism underlying the healing effect of prosociality on trauma.

Whether benefits observed here could be generalized beyond lab settings remains an open question. In the present research, prosocial behaviour is not directly related to contents from the trauma films. However, survivors of trauma may engage in prosocial behaviour that remind them of their own suffering, e.g., donating blood or money to earthquake victims could remind an earthquake survivor of their own traumatic past. On the one hand, exposure to reminders may reinstate traumatic memories and thus reinforce PTSD symptoms (Glad et al., 2017). On the other hand, prosocial behaviour could provide trauma survivors with opportunities to confront with trauma and to positively reappraise their traumatic experiences via meaning-making, which may facilitate their recovery from trauma (see Nickerson et al., 2017). Moreover, we designed both prosocial and proself tasks to be cost-free so as to induce subjective experience of prosociality or proself among participants, instead of measuring individual differences in prosocial vs. proself tendencies. However, real-life prosocial behaviour would often incur costs, e.g., donating to a charity would incur financial self-cost. Future research could examine whether cost associated with prosocial engagement (e.g., no-cost vs. low-cost vs. high-cost) could differentially impact trauma-related symptoms.

Another important factor to consider is the timing of prosocial acts relative to trauma. Unlike lab studies in which participants engaged in prosocial behaviour immediately following the traumatic exposure, prosocial help in daily life can occur during a prolonged period following trauma. Whether immediacy of prosocial acts is a key to realize the benefits observed here remains an open question, but there are reasons to be optimistic. Specifically, prosocial behaviour taps into psychological mechanisms such as meaning-making (e.g. Vollhardt, 2009; Vollhardt & Staub, 2011), disengagement from self-referential thinking (e.g. Michael et al., 2007; Sartory et al., 2013), and experiences of positive affect (Aknin et al., 2020; Marks et al., 2018; for meta-analytical evidence, see; Curry et al., 2018; Hui et al., 2020), which could facilitate posttraumatic growth and thus alleviate trauma-related symptoms. An important goal for future research is to investigate *when* and *what forms* of prosocial engagement can be effective in reducing traumatic intrusions and alleviating trauma-related symptoms.

Limitations and other future directions should be noted. To manipulate prosocial behaviour, we employed a prosocial charity donation task that has been widely used in previous lab-based prosocial research (Hare et al., 2010; Moll et al., 2006). However, it must be noted that people's prosocial choices and the benefits could be influenced by their income levels and socio-economic status, which were not accounted for in the current study. Future research could consider various types of prosocial behaviour in naturalistic settings such as offering emotional support, volunteering, etc. to enrich our understanding on how prosocial engagements could buffer trauma-/stress-related symptoms. Another limitation of the present research is that our sample was largely skewed toward females (79.44% of participants are female across Experiment 1 & 2). Overrepresentation of female participants in psychological research is a well-documented issue (Barlow & Cromer, 2006; Dickinson et al., 2012; McCray et al., 2005) and is also present in research employing the trauma film paradigm (e.g. 69%–100% female participants see Porcheret et al., 2015; Schaich et al., 2013; van Schie et al., 2019). Even though gender was not a significant covariate, nor did it influence the results, future studies should aim to balance the male-female ratio in their samples, given documented gender differences in prosociality (e.g. Eisenberg et al., 2007; Hine & Leman, 2014).

Another caveat is that we did not measure participants' perception on the believability of the cover story about the prosocial task. We took steps as precautions to mitigate the concerns: first, participants indicated their preferred charities among a list of well-known local charities before the experiment; second, we used participants personally preferred charity in the prosocial task; third, participants signed donation forms as proof of their donation after the prosocial task. Future research shall test how such perception may influence prosocial behaviour's psychological benefits. Lastly, it remains unclear as to whether explicit instructions to record trauma intrusions in the diary would lead to over- or under-estimation of the intrusion frequency, relative to spontaneous occurrence of intrusive memories without such instructions and diaries. Future research could compare frequencies of intrusions recorded in intrusion diaries with retrospective count of intrusions in a no-instructions condition to offer clarity on this issue.

To conclude, we found that performing prosocial charity donations causally reduced unwanted traumatic intrusions in participants' daily life outside the lab setting. This finding is noteworthy given that intrusive memories/thoughts are hallmark and transdiagnostic symptoms of psychiatric disorders including PTSD, depression, anxiety (Hu et al., 2017; Iyadurai et al., 2019; James et al., 2016). Prosocial engagement could be an effective socio-emotional approach in reducing involuntary trauma intrusions and trauma-related symptoms. In the aftermath of a traumatic event, people may engage in various forms of prosocial behaviour, such as providing emotional support to those in need, volunteering in one's community, donating to personally meaningful charities, among others. Given prosocial behaviour's positive impacts for the help-recipients, and its well-documented psychological benefits for help-providers, prosocial behaviour bears promises in safeguarding well-being and promoting resilience in the aftermath of trauma.

Data and code availability

https://osf.io/jvf5a/.

CRediT authorship contribution statement

Mohith M. Varma: Conceptualization, Methodology, Software, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization. **Xiaoqing Hu:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition.

Declaration of competing interest

Declarations of interest: None. The authors declare no conflict of interest.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.brat.2021.103998.

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