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Cognitive processing, memory, and the development of PTSD symptoms: two experimental analogue studies

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Abstract

Memory deficits are implicated in the development of posttraumatic stress disorder (PTSD). *Intentional* recall of trauma memories is frequently disorganised or incomplete, whilst *involuntary* memory fragments are easily triggered by perceptual cues. Ehlers and Clark (Behaviour Research and Therapy 38 (2000) 319–345) propose that a predominance of data-driven processing (i.e., processing sensory impressions) during the trauma contributes to the development of this memory pattern, and therefore, predicts PTSD symptoms after trauma. Two experimental studies examined these hypotheses. Student volunteers viewed a distressing videotape as an analogue for a traumatic event. In Study 1, cognitive processing was manipulated; in Study 2, extreme scorers on a processing screening questionnaire were pre-selected. The results indicated that data-driven processing is associated with the development of PTSD-like memories and analogue symptoms.

Keywords: Memory; Posttraumatic stress disorder; Cognitive processing; Intrusions

1. Introduction

Posttraumatic stress disorder (PTSD) is characterised by disturbances of memory. The hallmark symptoms of PTSD are *involuntary* distressing and uncontrollable

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memories of the precipitating trauma. These unusually vivid memories are experienced in a variety of sensory modalities and generally constitute segments of the episode rather than the whole event. They are often triggered by perceptual cues that resemble those present at the time of the trauma (Ehlers & Clark, 2000; Ehlers et al., 2002; van der Kolk & Fisler, 1995). Conversely, individuals with PTSD may simultaneously experience problems in *intentionally* recalling the traumatic event (e.g., Tromp, Koss, Figueredo, & Tharan, 1995; van der Kolk & Fisler, 1995). The order of events during the trauma is often sequentially confused, and there may be amnesia for a significant part or parts of the experience.[1]

How does the pattern of poor intentional recall and easy triggering of involuntary memories in PTSD develop? Many trauma theorists have proposed that the overwhelming nature of traumatic experiences prevents individuals from fully processing them at the time (e.g., Brewin, Dalgleish, & Joseph, 1996; Ehlers & Clark, 2000; Foa & Hearst-Ikeda, 1996; Horowitz, 1976; Siegel, 1995; van der Kolk & Ducey, 1989). In one such theoretical approach, Ehlers and Clark (2000) applied experimental psychology research on the relationship between information processing during encoding and the quality of subsequent memories to PTSD. The authors suggested that the memory pattern in PTSD may, in part, be the result of a predominance of data-driven processing during trauma (i.e., processing sensory impressions and perceptual characteristics rather than the meaning of the event) as opposed to conceptual processing (i.e., processing the meaning of the event, processing it in an organised way and placing it in context). Individuals who mainly engage in data-driven processing during trauma are expected to be at greater risk of developing PTSD symptoms than those who elaborate the contextual and meaning elements of the event (see also Siegel, 1995). This hypothesis is based on research indicating that (1) deeper, conceptually based processing results in elaborative encoding in memory and is required for intentional recall (Schacter, 1996), (2) data-driven processing results in a poorly elaborated, perceptually encoded memory trace that can be involuntarily retrieved by matching perceptual stimuli (Roediger, 1990), retrieval of information from memory being facilitated if retrieval conditions match those present during encoding (transfer-appropriate processing, Brown & Craig, 2000), and (3) elaboration of autobiographical memories inhibits unintentional retrieval (Conway & Pleydell-Pearce, 2000). Correlational evidence for the role of data-driven processing in the development of PTSD was found in three prospective studies of motor vehicle accident victims (Ehlers, Mayou, & Bryant, in press b;

[1] These observations appear to be at odds with laboratory studies of memory for criminal events showing that eyewitnesses remember *central* elements of the event well, but have relatively poor memory for *peripheral* information (reviewed by Christianson, 1992). Indeed, clinical observations suggest that PTSD patients may have problems in accessing even central information, e.g., whether the assailant had a knife, although they will usually remember the "gist" of the event. Furthermore, systematic observations of PTSD patients have suggested that intrusive memories include stimuli that were peripheral to the meaning of the event, but were temporally associated with the onset of the trauma or moments when the meaning of the event became more traumatic (Ehlers et al., in press). Since eyewitness research has used measures of intentional retrieval, it is not clear whether this literature is contradicted by observations relating to *involuntary* intrusive memories in PTSD.

Murray, Ehlers, & Mayou, 2002; Rosario, Williams, & Ehlers, 2002), and a prospective study of assault survivors (Halligan, Michael, Clark, & Ehlers, 2002). The present studies sought experimental evidence for the role of data-driven processing in subsequent poor recall and PTSD symptoms.

A further goal of the present studies was to specifically investigate whether poor intentional recall directly predicts the development of PTSD. As noted above, work by Conway (Conway & Pleydell-Pearce, 2000) suggests that one of the functions of elaboration of autobiographical memories is to inhibit unintentional retrieval of memories. Thus, insufficient elaboration will render the memory trace more vulnerable to triggering by matching sensory cues, increasing the frequency of PTSD symptoms such as intrusions and arousal (Ehlers & Clark, 2000). Preliminary research has provided correlational evidence for a relationship between poor intentional recall of the trauma and PTSD symptoms. Studies have found that trauma memory disorganisation predicts subsequent symptoms of acute stress disorder and PTSD following road traffic accidents (RTAs) (Harvey & Bryant, 1999; Murray et al., 2002), and assault (Amir, Stafford, Freshman, & Foa, 1998; Halligan et al., 2002). Foa, Molnar, and Cashman (1995) reported that recovery during reliving therapy in rape victims was associated with the formation of more coherent narratives for the event.

The present paper describes two analogue studies investigating the hypothesised relationships between data-driven processing, intentional recall, and PTSD-like symptoms following exposure to distressing material. Study 1 attempted to experimentally manipulate processing during exposure to the analogue traumatic stressor, whereas Study 2 examined the effects of natural variations of this dimension by selecting extreme groups.

2. Study 1

2.1. Method

2.1.1. Experimental design and participants

Student participants were allocated to one of two groups: the conceptual processing group ($n = 30$; 16 men and 14 women) or the data-driven processing group ($n = 31$; 17 men and 14 women). Stratified random allocation ensured the groups were matched for trait anxiety scores and gender. Participants watched a distressing videotape as an analogue traumatic event, following instructions to engage in cognitive processing appropriate to their group allocation. At a second assessment participants performed a memory test for the videotape, and completed analogue symptom measures.

2.1.2. Materials

2.1.2.1. Road traffic accident (RTA) videotape. The analogue trauma consisted of 12 min of videotaped real-life footage compiled by Steil (1996) from training films for accident and emergency staff, showing the aftermath of RTAs; survivors' physical

injuries and psychological distress, dead bodies, car wreckage. Participants viewed the videotape on a 46 in screen, listening through headphones.

2.1.3. Measures

Participants completed the following standardised measures: the Beck depression inventory (BDI; Beck, Ward, Mendleson, Mock, & Erbaugh, 1961), the state (STAIS) and trait versions (STAIT) of the state and trait anxiety inventory (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs 1983) and the trait dissociation questionnaire (TDQ; Murray et al., 2002). Prior research has indicated that PTSD is associated with depression, anxiety, and dissociation, and pre-existing differences in these dimensions may predispose to the development of PTSD. We assessed these potential confounds, and controlled for them where appropriate.

The *cognitive processing questionnaire*[2] was developed through a series of studies carried out by the authors (Ehlers, 1998; Halligan et al., 2002; Murray et al., 2002; Rosario et al, 2002) to assess data-driven versus conceptual processing of traumatic material. Data-driven items assess the degree to which the individual primarily processed surface, perceptual aspects (e.g., "It was like a stream of unconnected impressions following each other"). Conceptual processing items relate to deeper processing of the meaning of the situation (e.g., "I had a clear impression of how one event followed from another"). This questionnaire has previously been shown to have satisfactory to good internal consistencies in patient and student populations (Chronbach's alphas of 0.7 and above; Ehlers, 1998), and to predict both narrative disorganisation and the development of PTSD in prospective studies of motor vehicle accident victims (Rosario et al., 2002) and assault victims (Halligan et al., 2002). Internal consistencies in the present sample were satisfactory (data-driven processing, 8 items, Chronbach's alpha = 0.69; conceptual processing, 7 items, alpha = 0.76).

The *symptoms questionnaire* assessed the occurrence of analogue PTSD symptoms in the week following the videotape. Participants rated daily frequency of video-related intrusions, the average distress associated with intrusions, and increases in both fear and avoidance of road-related situations since viewing. In addition, 12 items measured frequency of analogue PTSD symptoms, with 4 items each devoted to intrusion (alpha = 0.81), avoidance (alpha = 0.95), and arousal (alpha = 0.92) symptoms.

A *verbal free recall task* for material from the videotape assessed the hypothesised deficits in incidental free recall. Participants were instructed to describe everything that they could recall, paying attention to the correct sequence of events, and were given 10 min alone to complete the task. Audio taped descriptions were transcribed and then scored blind (S.L.H.). Ratings were based on chronological listings of all the events occurring in the videotape. As a measure of content, transcripts were scored for the number of these events that they included. As a measure of memory coherence, transcripts were scored for the proportion of included events which were recalled in the correct order (Wegner, Quilian, & Houston, 1996). Scoring of recall

[2] A copy of the questionnaire is available from Anke Ehlers (mailto: c.goddard@iop.kcl.ac.uk).

order was item to item and strictly sequential. A random sample of 30 transcripts was scored by a second blind rater. Inter-rater agreement was sufficient for measures of content ($r = 0.88$, $p < 0.001$) and coherence ($r = 0.75$, $p < 0.001$).

2.1.4. Processing manipulation

The processing manipulation was implemented through instructions given to the data-driven and conceptual groups. Prior to watching the RTA videotape participants underwent a 10 min training phase, practising the processing instructions appropriate to their group allocation on non-traumatic videotape footage taken from a feature film.

The *data-driven processing* group was instructed as follows: "Become absorbed in the images and sounds. Instead of trying to work out what is going on, try to let yourself be carried away by the things you can see, the sounds you can hear and the physical sensations the people might be experiencing. See each scene as a series of unconnected snapshots and let the images and sounds impress themselves upon you."

The *conceptual processing* group was instructed as follows: "Concentrate on the story. Ask yourself what is happening to the people in the scene and why. Figure out what is going on and what might happen next. Stay with the storyline as it unfolds in front of you."

2.1.5. Procedure

Participants attended two sessions. In the first session, participants completed the BDI, the TDQ and the STAI before being allocated to either the data-driven or conceptual group. After training on non-traumatic footage, participants watched the RTA videotape whilst following the processing instructions appropriate to their group allocation. Participants then completed the cognitive processing questionnaire and the STAIS with respect to their anxiety during the videotape. The second session took place one week later. Participants completed the symptoms questionnaire and carried out the video free recall task.

2.2. Results

2.2.1. Group characteristics

Means and standard deviations are shown in Table 1. The groups were matched in terms of gender distribution, and BDI, STAIT, TDQ and initial STAIS scores.

2.2.2. Cognitive and emotional responses to the videotape

Means and standard deviations are reported in Table 1. STAIS scores were subjected to a two-way group (data-driven versus conceptual) by time (initial versus video STAIS score) repeated measures analysis of variance (ANOVA). A significant main effect of time [$F(1,59) = 64.1$, $p < 0.001$] indicated that anxiety increased during the videotape. There was no group by time interaction [$F(1, 59) = 0.7$, n.s.], therefore the groups experienced similar increases in anxiety during the videotape.

Table 1
Group characteristics and videotape responses for Studies 1 and 2, means and standard deviations (in parentheses)

	Study 1		Study 2	
	Data-driven group	Conceptual group	Data-driven group	Conceptual group
Age (yr)	20.3 (1.7)	20.2 (2.0)	20.8 (4.3)	23.9 (7.1)
Trait cognitive processing questionnaire				
Data-driven score (0–4)	—	—	2.4 (0.5)	0.8 (0.4)
Conceptual score (0–4)	—	—	1.7 (0.5)	3.1 (0.5)
Depression (BDI)	4.9 (3.5)	5.5 (3.3)	6.1 (5.4)	6.3 (9.9)
Trait anxiety (STAIT)	39.3 (8.3)	39.9 (7.8)	43.7 (10.0)	36.7 (10.8)
State anxiety before exposure (STAIS)	33.6 (7.4)	35.0 (6.8)	37.3 (8.6)	32.2 (8.1)
Trait dissociation (TDQ)	50.6 (18.3)	49.4 (16.7)	56.4 (27.7)	39.1 (26.3)
Intelligence (Mill Hill)	—	—	105.0 (10.7)	110.2 (8.9)
Responses to the videotape				
State anxiety after exposure (STAIS)	44.4 (12.5)	44.0 (9.3)	50.9 (11.8)	42.9 (12.8)
Videotape cognitive processing questionnaire				
Data-driven score (0–4)	2.4 (0.5)	2.1 (0.4)	1.6 (0.7)	0.9 (0.5)
Conceptual score (0–4)	1.9 (0.4)	2.7 (0.5)	2.0 (0.7)	2.5 (0.7)

BDI: Beck depression inventory; STAIT: trait version of the state-trait anxiety inventory; STAIS: state version of the state-trait anxiety inventory; TDQ: trait dissociation questionnaire.

In terms of cognitive responses to the videotape, scores on the cognitive processing questionnaire indicated group differences in accordance with instructions; the conceptual group reported engaging in more conceptual processing than the data-driven group [$t(58) = 6.8$, $p < 0.001$], and the data-driven group reported more data-driven processing [$t(58) = 2.2$, $p < 0.05$]. However, the magnitude of the group difference was small (0.3 per item, possible range 0–4).

2.2.3. *Video free recall task performance*

Incidental free recall task performance was in support of hypotheses. The data-driven group scored lower in terms of memory coherence, recalling a smaller proportion of events from the videotape in the correct order [data-driven group $= 0.48 \pm 0.20$, conceptual group $= 0.67 \pm 0.12$, $t(48.5) = -4.6$, $p < 0.001$]. The data-driven group also recalled fewer events from the videotape compared to the conceptual group [data-driven group $= 15.2 \pm 5.3$, conceptual group $= 21.2 \pm 6.5$, $t(59) = -4.0$, $p < 0.001$].

2.2.4. Analogue PTSD symptoms

Group comparisons of scores on the symptoms questionnaire did not support hypotheses. There were no group differences on any of the analogue symptom measures.

Since the experimental manipulation was only modestly successful in influencing the degree of data-driven processing participants engaged in, a post hoc analysis examined the effects of the actual amount of data-driven processing reported during the videotape. Zero-order correlations between scores on the cognitive processing questionnaire and scores on the 1 week follow-up measures confirmed the hypothesised association between data-driven processing and memory disorganisation ($r = -0.31$, $p < 0.05$), and also provided evidence for the predicted role in symptom development. Data-driven processing was positively correlated with the degree of distress associated with memories of the videotape ($r = 0.44$, $p < 0.005$), and reported avoidance of road-related situations since watching the videotape ($r = 0.28$, $p < 0.05$). There was also a significant correlation between degree of data-driven processing and the number of analogue symptoms reported ($r = 0.31$, $p < 0.02$).

2.2.5. Direct association between disorganisation of memory and analogue PTSD symptoms

Zero-order correlations between coherence scores on the free recall task and analogue symptoms were calculated in order to test for the hypothesised association between memory disorganisation and symptoms. There was a negative correlation between degree of coherence and arousal symptoms ($r = -0.28$, $p < 0.05$), but memory coherence was not related to the other symptom clusters.

2.3. Discussion

Study 1 found that data-driven processing during exposure to distressing material is associated with poor subsequent intentional recall. The experimental groups differed in terms of both coherence and completeness of memory. This is in line with the hypothesis that data-driven processing makes subsequent retrieval both less organised and less complete.

However, the hypothesis that data-driven processing has a role in the development of analogue PTSD symptoms received little support when the groups receiving data-driven versus conceptual instructions were compared. Since experimental instructions had relatively modest effects on how participants processed the videotape, individual differences in the tendency to engage in predominantly data-driven versus predominantly conceptual processing may have masked the effects of the experimental manipulation. A post hoc analysis found that the actual degree of data-driven processing, regardless of experimental group, was associated with symptom levels. Study 2 averted the problem of artificially manipulating cognitive processing by instead capitalising on natural variations in individual processing style.

In contrast to research that has reported an association between memory disorganisation and the development of PTSD, the hypothesised role of memory disorganisation in the development of analogue PTSD symptoms received little support. Narrative disorganisation scores were related to only one of the three analogue symptom clusters in Study 1. The measure of disorganisation developed for the present study assessed accuracy of sequential information. This measure may have been too strict as the videotape was comprised of several unrelated parts, and confusion of the sequence of these parts may not have necessarily indicated incomplete processing. Furthermore, it is conceivable that individuals formed a memory for the videotape which was both coherent and integrated, despite being relatively inaccurate or incomplete. Studies of trauma survivors do not have veridical accounts by which to assess trauma memory accuracy, but rather have examined survivors' own accounts and perceptions of their memory. In order to allow for the possibility that memories which are factually inaccurate may still be experienced as being coherent and complete, Study 2 incorporated a second, self-report memory assessment, which examined participants' own perceptions of their memory for the videotape, both in terms of disorganisation and intrusive qualities.

A second consideration is that memory for the videotape may have altered in the week following viewing, prior to assessment. The experience of frequent intrusive symptoms could enhance memory at follow-up, overshadowing any initial association between memory deficits and analogue symptoms. Participants in Study 2 completed the video recall task immediately following the videotape. In order to ensure that memory was still assessed at 1 week follow-up, the memory questionnaire was completed at this time point.

The groups were pre-selected for a potentially maladaptive variable, which could overlap with other indices of psychological disturbance that have already been shown to predict PTSD symptoms. Therefore, potential confounds—initial depression, anxiety and dissociation—were assessed as for Study 1, and covaried out in group comparisons. Study 2 additionally examined verbal intelligence, since this could influence memory and cognitive processing, and some studies have found IQ to be related risk for PTSD.

3. Study 2

3.1. Method

3.1.1. Participants

Students were recruited from a sample of 579 who completed a "trait" version of the cognitive processing questionnaire. Selection ensured that the groups were matched for gender. Participants in the data-driven group scored in the upper quartile for data-driven questions and below the median value for conceptual questions ($N = 29$; 15 men and 14 women). Participants in the conceptual group scored in the upper quartile for conceptual questions and below the median value for the data-driven questions ($N = 28$; 15 men and 13 women).

3.1.2. Measures

In addition to the questionnaires employed in Study 1, the Mill Hill Vocabulary Scale (Raven, Court, & Raven, 1982) assessed verbal ability. Furthermore, participants were pre-selected using a "trait" version of the cognitive processing questionnaire. In this questionnaire, participants were instructed to think of personal experiences that they found very stressful or negative, and then responded to items whilst keeping their reactions to these events in mind. Thus, the questionnaire assessed the type of processing that individuals reported engaging in during previously experienced unpleasant or stressful life events, i.e., their cognitive responses to stress. Items were modified in order to create a set appropriate for a generic event; the trait questionnaire consisted of 11 data-driven (alpha = 0.90) and 6 conceptual processing items (alpha = 0.79). The processing questionnaire assessing responses to the videotape was modified to incorporate the same items; data-driven items (alpha = 0.88), conceptual items (alpha = 0.78).

3.1.3. Memory measures

The *incidental free recall task* (Study 1) was carried out immediately following the videotape.

The *videotape memory questionnaire* assesses disorganisation of memory for the videotape (4 items; alpha = 0.88) (e.g., "I cannot get what happened during the videotape straight in my mind"), and the extent to which this memory consists of vivid, emotional, easily triggered intrusions (6 items; alpha = 0.76) (e.g., "My memory for the videotape consists of vivid images").

The *autobiographical memory questionnaire* assessed the characteristics of a personal negative life event. Participants briefly described "one of their most unpleasant experiences" and rated their distress during the event on a 0–100 point visual analogue scale, prior to completing 5 items (alpha = 0.90) relating to disorganisation of memory for the event, and 8 items (alpha = 0.84) relating to intrusive qualities.

3.1.4. Procedure

The trait version of the cognitive processing questionnaire was completed by a large pool of respondents several weeks prior to commencement of the study. Scores on this measure were used to pre-select participants, as already described. Selected participants attended two sessions, 1 week apart. In session 1, participants completed the BDI, STAI, TDQ, Mill Hill Vocabulary Scale and the autobiographical memory questionnaire prior to watching the videotape. Participants subsequently completed the cognitive processing questionnaire and the STAIS, with respect to their reactions to the film. After a 10 min break, participants carried out the free recall task. In session 2, participants completed the symptoms questionnaire and the videotape memory questionnaire.

3.2. Results

3.2.1. Group characteristics

Table 1 indicates that the data-driven processing and conceptual processing groups differed in anxiety and trait dissociation. The data-driven group scored higher on the STAIT [$t(55) = 2.6$, $p < 0.02$], STAIS [$t(55) = 2.3$, $p < 0.05$], and the TDQ [$t(55) = 2.4$, $p < 0.02$]. Furthermore, the conceptual group performed better on the Mill Hill Vocabulary test [$t(55) = -1.9$, $p < 0.05$]. These pre-existing differences are controlled for in subsequent analyses. Selection procedures ensured group differences in trait cognitive processing score, the data-driven group scoring higher in terms of data-driven processing [$t(55) = 14.7$, $p < 0.001$] and lower in terms of conceptual processing [$t(55) = -9.8$, $p < 0.001$] relative to the conceptual group.

3.2.2. Responses to the videotape

Cognitive and emotional responses to watching the videotape are detailed in Table 1. Scores on the cognitive processing questionnaire indicated that the data-driven group reported engaging in more data-driven [$t(55) = 4.0$, $p < 0.001$] and less conceptual processing [$t(55) = -2.9$, $p = 0.006$] during the videotape.

STAIS scores in response to the videotape were examined using a two-way group (data-driven versus conceptual) by time (initial versus video) repeated measures ANOVA. A significant main effect of time [$F(1, 55) = 57.5$, $p < 0.001$] indicated that anxiety increased during viewing. There was no group by time interaction [$F(1, 55) = 0.7$, $p = 0.41$], thus the groups experienced similar increases in anxiety during the video.

3.2.3. Group comparisons on outcome measures

All group comparisons were performed using one-way analyses of covariance (ANCOVA), with STAI (state and trait), Mill Hill, TDQ and BDI scores as covariates.

3.2.4. Differences in memory characteristics

Means and standard deviations are reported in Table 2. In terms of the videotape memory questionnaire, completed at 1 week follow-up, the data-driven group scored twice as high as the conceptual group on the memory disorganisation scale, $F(1, 49) = 12.9$, $p < 0.001$. Thus, the results were in accordance with hypotheses and with the free recall data collected at the same time point in Study 1. In addition, the data-driven group reported more sensory, distressing and intrusive recollections relating to the videotape, $F(1, 49) = 8.3$, $p < 0.01$. The free recall task, carried out immediately following the videotape in Study 2, did not replicate the positive results from Study 1; there were no group differences in videotape memory as assessed by this task.

The data-driven and conceptual groups described autobiographical events that were comparable in terms of the emotional distress they evoked (rated on a 0–100 point scale; mean = 79.1, SD = 26.4, and mean = 76.1, SD = 24.4, respectively), the objective severity of the event (0–5 point scale; mean = 2.7, SD = 0.9, and mean = 2.5,

Table 2
Group differences in memory characteristics and analogue PTSD symptoms in Study 2[a]

	Data-driven group	Conceptual group	Statistic[b]	*p*-value
Videotape free recall task				
Number of events recalled	21.7 (7.8)	22.1 (9.7)	F(1,50) = 0.0	0.91
Proportion recalled in correct order	0.69 (.16)	0.71 (.16)	F(1,50) = 0.2	0.63
Videotape memory questionnaire (0–4)[c]				
Intrusion score	1.1 (0.6)	0.7 (0.5)	F(1,49) = 8.3	<0.01
Disorganisation score	1.4 (0.9)	0.7 (0.7)	F(1,49) = 12.9	<0.001
Autobiographical memory questionnaire (0–4)				
Intrusion score	1.3 (0.9)	0.7 (0.7)	F(1,49) = 4.0	0.05
Disorganisation score	1.4 (0.9)	0.7 (0.7)	F(1,49) = 6.2	<0.05
Symptoms questionnaire				
Intrusion frequency	1.6 (0.9)	1.1 (0.7)	F(1,50) = 5.7	<0.05
Intrusion related distress (0–100)[d]	39.6 (22.5)	14.6 (17.6)	F(1,43) = 12.0	<0.005
Increased fear on roads (0–100)	23.3 (24.1)	7.6 (16.4)	F(1,50) = 4.8	<0.05
Increased avoidance on roads (0–100)	12.7 (22.6)	2.1 (6.7)	F(1,50) = 2.4	0.12
PTSD "symptoms" (0–4)	1.7 (0.5)	1.3 (0.4)	F(1,50) = 9.8	<0.005

[a] $N = 49$: 25 data-driven, 24 conceptual participants.
[b] Analysis of covariance, co-varying for trait and state anxiety, depression, trait dissociation, Mill Hill score.
[c] $N = 56$: 29 data-driven, 27 conceptual participants.
[d] Completed only by those participants reporting intrusions. $N = 50$: 26 data-driven, 24 conceptual participants.

SD = 0.8), and the time since the experience (mean = 4.8 yr, SD = 5.3, and mean = 4.1 yr, SD = 6.3). The data-driven group scored higher on the disorganisation scale of the autobiographical memory questionnaire, $F(1, 49) = 5.4$, $p < 0.05$, suggesting that trait processing style may also influence memory for actual events. The events reported by the two groups were comparable in terms of reported distress at the time, severity as scored by an independent, blind rater, and time since the event.

3.2.5. Analogue PTSD symptoms

Group comparisons are reported in Table 2. The data-driven group reported more analogue PTSD symptoms in the week following the videotape. In particular, they experienced more frequent intrusions ($p < 0.05$) and rated them as being more distressing ($p < 0.001$). They also reported experiencing more traffic-related fear since the videotape ($p < 0.05$) and scored higher in terms of PTSD symptoms ($p < 0.01$), particularly avoidance ($p < 0.02$) and arousal ($p < 0.05$) symptoms.

Table 3
Correlations between self-reported memory disorganisation score and analogue PTSD symptoms in Study 2

Variable	Memory disorganisation score	
	Correlation	*p*-value
Videotape memory questionnaire[a]		
Intrusion score	0.43	<0.001
Symptoms questionnaire		
Frequency of intrusions	0.12	0.40
Intrusion-related distress (0–100)[b]	0.27	0.06
Increased fear on roads (0–100)	0.38	<0.005
Increased avoidance on roads (0–100)	0.19	0.17
PTSD "symptoms" (0–4)	0.39	<0.005

[a] $N = 56$: 29 data-driven, 27 conceptual participants.
[b] Completed only by those participants reporting intrusions. $N = 49$: 25 data-driven, 24 conceptual participants.

3.2.6. Association between disorganisation of memory and analogue PTSD symptoms

Zero-order correlations between disorganisation scores on the videotape memory questionnaire and analogue PTSD symptoms are reported in Table 3. Importantly, the results provided strong support for hypotheses. Disorganisation was associated with more intrusive, perceptually based memories as assessed by the memory questionnaire ($r = 0.43$), and with the occurrence of analogue intrusion symptoms ($r = 0.35$). Disorganisation also correlated with overall levels of analogue symptoms ($r = 0.39$), particularly avoidance symptoms ($r = 0.41$) and increases in traffic-related fear ($r = 0.38$). In contrast, narrative disorganisation scores from the verbal recall task did not correlate with any of the analogue symptom measures.

3.2.7. Mediational analysis

Ehlers and Clark (2000) hypothesised that data-driven processing during trauma increases the probability of subsequent reexperiencing symptoms. There are two pathways for this relationship. First, data-driven processing should facilitate triggering of trauma memories by matching sensory cues (transfer appropriate processing). Second, following Conway and Pleydell-Pearce's (2000) observation that elaboration of autobiographical memories inhibits involuntary recall, data-driven processing should lead to less effective inhibition of involuntary recall. If the latter pathway is important, a poorly elaborated memory for traumatic material should act as a mediator in the relationship between data-driven processing of that material and subsequent reexperiencing symptoms. We tested this hypothesis by analysis of covariance. Self-reported memory disorganisation, but not free recall measures, met prerequisite requirements for a potential mediator, as differences in levels of data-driven processing predicted self-reported disorganisation scores and disorganisation was significantly related to levels of reexperiencing. Therefore,

disorganisation scores on the videotape memory questionnaire were included as a covariate for the comparison between the data-driven and conceptual processing groups on reexperiencing symptoms. In line with the hypothesis that poor intentional recall mediates the relationship between data-driven processing and subsequent reexperiencing symptoms, the group difference ceased to be significant [$F(1, 53) = 2.11$; n.s.].

3.3. Discussion

Study 2 found data-driven processing to be positively associated with degree of self-reported disorganisation of memory, both for the distressing videotape and for a personal autobiographical event. Data-driven processing also predicted higher levels of analogue PTSD symptoms following the videotape. In line with studies of PTSD populations, self-reported memory deficits were associated with analogue symptoms.

In contrast to Study 1, Study 2 did not find an association between data-driven processing and performance on the verbal free recall test of memory. The free recall task was carried out immediately following the videotape in Study 2, rather than 1 week later as in Study 1. Performance may, therefore, have been relatively strongly influenced by short-term memory, rather than longer-term encoding.

4. General discussion

The main aim of the current research was to investigate the role of data-driven processing in the development of PTSD-like memories and symptoms (Ehlers & Clark, 2000). In both studies, there was evidence for a positive relationship between data-driven processing and incoherent, disorganised and less detailed recall. Furthermore, in Study 2 this association was independent of individual differences in dissociation and state anxiety, two factors that have previously been shown to have implications for the encoding of traumatic material (e.g., Harvey & Bryant, 1999; Krystal, Bennett, Bremner, Southwick, & Charney, 1995; Murray et al., 2002). In addition, both studies supported the hypothesis that data-driven processing during exposure to distressing material enhances the probability that the individual will develop reexperiencing and other PTSD-like symptoms. Study 2 also demonstrated that the association between data-driven processing and analogue symptoms was independent of other factors that have been shown to predict PTSD symptoms; dissociation, anxiety, depression, and intelligence.

In line with research that has found memory disorganisation to predict the development of PTSD symptoms in traumatised populations (Halligan et al., 2002; Harvey & Bryant, 1999; Murray et al., 2002), correlational analyses found degree of memory disorganisation to be associated with subsequent arousal symptoms (Study 1), or avoidance and intrusion symptoms (Study 2). In addition, the proposal that deficits in intentional recall mediate the relationship between cognitive processing

and reexperiencing symptoms was supported in Study 2. Differences in symptom levels between the data-driven and conceptual processing groups were no longer significant once memory disorganisation was controlled for.

Inconsistent results were obtained using the verbal free recall task to assess memory disorganisation. Performance on the free recall task was generally unrelated to the development of analogue symptoms. This is in contrast to results obtained by examining participants' own perceptions of their memories, and to prior research that has found memory disorganisation to be associated with PTSD symptoms in traumatised populations (Amir et al., 1998; Harvey & Bryant, 1999; Halligan et al., 2002; Murray et al., 2002). Furthermore, although cognitive processing predicted memory disorganisation in the free recall task in Study 1, this finding was not replicated in Study 2. The latter finding may relate to the methodological changes, the recall task being completed immediately following the videotape in Study 2 and at 1 week follow-up in Study 1. Consolidation of information in long term memory is an extended process, involving elaboration and integration of information into the memory base (Conway & Pleydell-Pearce, 2000). Data-driven processing, in providing relatively little meaning information, may interfere with such consolidation and thus impact more on long-term than short-term recall. Alternatively, individuals who engage in data-driven processing when confronted with distressing material may also engage in this type of processing when recalling that same material, resulting in a progressive detriment in memory over time. Notably, despite negative findings obtained with the free recall task completed immediately post-videotape in Study 2, the memory questionnaire completed 1 week later did find that data-driven processing predicted disorganisation.

The contradictory findings from the self-report versus free-recall memory assessments in Study 2 necessarily reduce the strength of our conclusions in this respect. One problem in interpreting these conflicting results lies in defining what constitutes a coherent and elaborated memory. In particular, the results raise the theoretically interesting question of whether veridical information pertaining to trauma memories is actually relevant to the prediction of subsequent reexperiencing symptoms.

Since veridical accounts of actual traumatic events are generally not available, prior reports of symptom-related memory disorganisation in PTSD have based their conclusions on examinations of the coherence of the narrative accounts given, not the accuracy. Therefore, it may be that actual fidelity is relatively unimportant in comparison to memory organisation, i.e., that coherent, but factually incorrect memories are just as protective as factually correct ones. In general, the fact that autobiographical recall is subject to inaccuracy and systematic distortion is well documented (Bartlett, 1932; Loftus & Loftus, 1980). Current theories of memory emphasise reconstructive as well as retrieval processes in the recall of autobiographical material, and memory is increasingly being perceived as being fluid and subjective, rather than indelible and reliable. Memory inaccuracies may be progressively introduced as information is assimilated into the memory base and incorporated with other ideas. Such inaccuracies may not necessarily correspond

with disorganisation or pathology; rather they are a part of the normal processes of assimilation, integration and retrieval. By only assessing the accuracy of sequence and content, the free-recall task may have confounded such non-pathological distortions with memory disorganisation.

Overall, the current results validate the concept of data-driven versus conceptual processing as a relevant dimension of cognitive processing during trauma; effects on memory for traumatic material and on subsequent analogue PTSD symptoms were independent of other variables that play a role in the aetiology of PTSD, including dissociative tendency, trait anxiety, depression, and intelligence. Future research should address the situational and individual factors that lead to disrupted cognitive processing. We assumed that individuals are prone to engaging in data-driven processing in the face of stressful or traumatic material; to the extent that traumatic experiences provoke a high state of arousal and fear, or require rapid assimilation of novel material, the capacity for in-depth processing may be overloaded. In addition, individual differences are presumed to influence the degree of stress required to provoke such a response, hence the "trait" measure applied in Study 2. However, since our studies did not examine responses to non-traumatic material, the extent to which data-driven processing is restricted to traumatic material is not known.

Although the strength of our conclusions is limited by the reliance on self-report assessments, our measures are validated by the fact that the current associations between processing, memory disorganisation and analogue PTSD symptoms replicate findings obtained using the same assessments in trauma-exposed groups (Halligan et al., 2002; Murray et al., 2002). Additional validity might be gained through more complex methodology, such as using a bi-directional processing manipulation in a within-subject design. A second limitation lies in drawing conclusions regarding reactions to traumatic events on the basis of reactions to relatively mild stimuli. However, the validity of the current research is supported by the finding that cognitive processing influenced memory for real-life negative events as well memory for the analogue trauma. Furthermore, factor analysis of PTSD symptoms suggests that it is a dimensional rather than a categorical disorder (Maes et al., 1998). The assessment of mild reactions should, therefore, yield results applicable to severe reactions, the difference being quantitative rather than qualitative. A major strength of the analogue design is that all participants were exposed to the same event; prior studies of trauma memory have not been able to control for event characteristics, and a veridical account of the event has not been available.

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