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Inter-identity amnesia in dissociative identity disorder resolved: A behavioural and neurobiological study

Lora I. Dimitrova [a,b], Andrew J. Lawrence [a], Eline M. Vissia [c], Sima Chalavi [d], Andreana F. Kakouris [e], Dick J. Veltman [b], Antje A.T.S. Reinders [a,*]

[a] Department of Psychological Medicine, Institute of Psychiatry, Psychology & Neuroscience, King's College London, London, UK
[b] Department of Psychiatry, Amsterdam UMC, Location VUmc, VU University Amsterdam, Amsterdam, the Netherlands
[c] Heelzorg, Centre for Psychotrauma, Zwolle, the Netherlands
[d] Research Center for Movement Control and Neuroplasticity, Department of Movement Sciences, KU Leuven, Leuven, Belgium
[e] Department of Psychosis Studies, Institute of Psychiatry, Psychology & Neuroscience, King's College London, London, UK

A R T I C L E I N F O

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Posttraumatic stress disorder
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Memory
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A B S T R A C T

Introduction: Dissociative identity disorder (DID) is characterised by, among others, subjectively reported inter-identity amnesia, reflecting compromised information transfer between dissociative identity states. Studies have found conflicting results regarding memory transfer between dissociative identity states. Here, we investigated inter-identity amnesia in individuals with DID using self-relevant, subject specific stimuli, and behavioural and neural measures.

Methods: Data of 46 matched participants were included; 14 individuals with DID in a trauma-avoidant state, 16 trauma-avoiding DID simulators, and 16 healthy controls. Reaction times and neural activation patterns related to three types of subject specific words were acquired and statistically analysed, namely non-self-relevant trauma-related words (NSt), self-relevant trauma-related words from a trauma-avoidant identity state (St), and trauma-related words from a trauma-related identity state (XSt).

Results: We found no differences in reaction times between XSt and St words and faster reaction times for XSt over NSt. Reaction times of the diagnosed DID group were the longest. Increased brain activation to XSt words was found in the frontal and parietal regions, while decreased brain activity was found in the anterior cingulate cortex in the diagnosed DID group.

Discussion: The current study reproduces and amalgamates previous behavioural reports as well as brain activation patterns. Our finding of increased cognitive control over self-relevant trauma-related knowledge processing has important clinical implications and calls for the redefinition of "inter-identity amnesia" to "inter-identity avoidance".

1. Introduction

Dissociative identity disorder (DID) is the most severe of trauma-related and dissociative disorders (Lebois et al., 2022; Reinders and Veltman, 2021). Experiencing repeated traumatisation during early childhood is believed to disrupt the unification of one's sense of self through the creation of mental and behavioural states designed to compartmentalise traumatic experiences and allow for normal functioning in daily life (Putnam, 1997). As such, trauma-related knowledge is held by trauma-related identity states while trauma-avoidant identity states subjectively report dissociative amnesia for childhood trauma-related knowledge (American Psychiatric Association, 2013; Reinders et al., 2003, 2006). The compartmentalisation of, and identity-state dependent access to, trauma-related knowledge has been referred to as *inter-identity amnesia*. Behavioural and neurobiological research in DID have shown contradicting evidence regarding the validity of inter-identity amnesia, but experimental paradigms and stimuli vary across studies, see for a recent review in Reinders et al. (2022).

The core characteristic and clinically relevant aspect of inter-identity amnesia in DID is that a trauma-avoidant identity state is unable to recall

* Corresponding author. Department of Psychological Medicine Institute of Psychiatry, Psychology and Neuroscience (IoPPN) King's College London, De Crespigny Park, London, SE5 8AF, UK.

E-mail addresses: a.a.t.s.reinders@gmail.com, a.a.t.s.reinders@kcl.ac.uk (A.A.T.S. Reinders).

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Table 1
Descriptives and statistical comparisons of response times for words within and between groups.

	Mean (SD)			ANOVA				*t*-test	
	dDID (n = 14)	sDID (n = 16)	HC (n = 16)	F(df)	Sig.	np^2	Mean difference	t(df)	Sig.
Age	44.86 (9.88)	40.14 (13.34)	43.38 (11.44)	0.604 (2)	0.551				
Years in education	15.14 (0.66)	15 (1.62)	15.20 (0.56)	0.238 (2)	0.872				
Word condition[a]									
St	3.19 (0.09)	3.14 (0.12)	3.12 (0.09)						
XSt	3.18 (0.10)	3.13 (0.11)	3.09 (0.08)						
NSt	3.18 (0.10)	3.11 (0.11)	3.06 (0.08)						
Within group comparisons									
XSt versus*[1] *St									
dDID								0.924 (13)	n.s.
sDID								1.779 (13)	p = 0.049
HC								2.687 (14)	p = 0.009
XSt versus*[2] *NSt									
dDID								−0.827 (13)	n.s.
sDID								−1.121 (13)	n.s.
HC								−5.396 (14)	p < 0.001
ANOVA									
Interaction effect[b]				2.779 (3.366, 67.317)	p = 0.042	0.122			
One tailed									
XSt *versus*[1] St				0.552 (2,40)	n.s.	0.027			
dDID vs HC							n.s.		
dDID vs sDID							n.s.		
XSt *versus*[2] NSt				−3.819 (2,40)	p = 0.030	0.160			
dDID vs HC							(−) 0.114		
dDID vs sDID							n.s.		

Note: dDID = diagnosed DID participants; sDID = simulated DID participants; HC = healthy control group; Sig. = significant p value; [a] = reaction time values log-transformed from milliseconds; [b] = Interaction effect (condition*group); St = trauma-avoidant identity state self-relevant trauma-related words; XSt = trauma-related identity state self-relevant trauma-related words; NSt = trauma-avoidant identity state non-self-relevant trauma-related words; [1] = directionality of the hypothesis in which XSt words are faster responded to than St words; [2] = directionality of the hypothesis in which XSt words are faster responded to than NSt words.

autobiographical self-relevant trauma-related information known by the trauma-related identity state (Nijenhuis, 2015; Nijenhuis et al., 2019). It has recently been formulated that this may be due to metacognitive deficits in allocating self-relevance to memories incoherent with their view of self (Dorahy, 2022). A recent review (as part of Reinders et al., 2022[1]) identified that only two sets of studies investigated this core aspect. One set of studies used only behavioural measures, that is, an autobiographical memory test and a memory retrieval test (Huntjens et al., 2014, 2016). Results of this set of studies showed that DID patients did not differ on memory specificity as compared to the control group and were also not completely dissociated from their trauma-related memories, disproving the notion of inter-identity amnesia. Specifically relevant to our current study are the response times (on page 424 of Huntjens et al., 2014) showing that self-relevant trauma-related knowledge is processed slower in a trauma-related identity state and faster in a trauma-avoidant identity state. This faster retrieval of specific memories in the trauma-avoidant state was proposed to reflect a strategy "to prevent the remembering of trauma-related memories triggered by the test cue words" (Dorahy, 2001; Huntjens et al., 2014, 2016). Of note, in the current paper we refer to this strategy as *cognitive avoidance* of self-relevant trauma-related memories. The underlying neural mechanisms of the proposed strategy were not studied. Furthermore, co-consciousness of knowledge between trauma-avoidant and trauma-related identity states was not evaluated *a priori,* which could explain the lack of inter-identity amnesia because the stimulus material used was not identity state specific enough to trigger compartmentalisation of knowledge. This stresses the need to investigate the trauma-avoidant identity state's response to specific trauma-related knowledge only held by the trauma-related identity state, thereby investigating the core notion of inter-identity amnesia. Nevertheless, if results are upheld with such specific stimulus material then it would be important to understand the underlying neural mechanisms facilitating DID patients' subjective sense of amnesia. The second set of studies used neural measures and script driven imagery paradigms to detect psychophysiological activation patterns (Reinders et al., 2003, 2006, 2012, 2014, 2016) but did not include behavioural measures. Trauma-avoidant identity states revealed identity state-dependent brain activation patterns including bilateral activation of middle and superior frontal regions as well as the bilateral intra-parietal sulcus and superior parietal regions, including the precuneus (Reinders et al., 2003, 2014). Although these findings are clinically important, they have not been studied conjointly with behavioural measures nor reproduced in an independent sample.

The joint neural and behavioural measures in the present study aim to investigate inter-identity amnesia for specific trauma-related and self-relevant knowledge in a trauma-avoidant identity state. To this end, we included three groups of participants: individuals with a diagnosis of DID, DID simulating controls, and healthy controls. Subject specific word stimuli were evaluated for self-relevance during event-related functional magnetic resonance brain-imaging and behavioural data collection. The first objective of this study was to investigate behavioural and neural responses of a DID trauma-avoidant identity state to their self-relevant trauma-related words (the "St" condition) as compared to self-relevant trauma-related words obtained from their trauma-related identity state (the cross-over or "XSt" condition). We further included non-self-relevant trauma-related (NSt) words to investigate whether the XSt words elicit similar behavioural and neural responses as the NSt words. This allows the investigation of whether the XSt words are being processed as non-self-relevant indicating a true cognitive avoidance of trauma-related knowledge, hence inter-identity amnesia. The second objective was to compare the diagnosed DID's responses to those of the DID simulating group and to those of a healthy

[1] See supplementary materials part 1 for a copy of the full table reviewing the inter-identity amnesia literature.

Table 2
Neural output of cortical and subcortical regions increased and decreased activation of XSt words.

L/R	Brain region	BA	Within group					Between group									
			dDID					dDID versus HC					dDID versus sDID				
			X	Y	Z	T^{*p}	kE^{c}	X	Y	Z	T^{*p}	kE^{c}	X	Y	Z	T^{*p}	kEˆc
<u>XSt versus St</u>																	
Increased bran activation																	
Cortical areas																	
L	Inferior Frontal gyrus	BA 8/9	−54	12	33	5.16	22^{1}										
R	Superior Frontal sulcus	BA 6/8						20	16	50	4.07	13					
L	Middle Frontal gyrus	BA 9	−50	23	40	4.74	22^{2}										
R	Middle Frontal gyrus	BA 8/9	44	19	36	5.1	17										
L	Middle Frontal gyrus	BA 6						−32	9	50	4.3	11	−29	16	47	3.52	10
R	Middle Frontal gyrus	BA 6						41	5	61	3.51	8^{1}					
								44	9	54	3.15^{p}	8^{2}					
L	PreCentral gyrus	BA 6						−43	−1	44	3.91	13					
L	Intra-Parietal sulcus	BA 7	−32	−57	50	3.57^{p}	9^{x}	−36	−57	40	4.37	$125^{**c,2}$					
R	Intra-Parietal sulcus	BA 7	34	−67	47	4.6	$45^{1,x}$	34	−67	47	3.64	$18^{x,1}$					
L	Superior Parietal lobule	BA 7	−22	−74	58	3.50^{p}	37^{3}	−40	−64	58	4.52	$125^{**c,1}$					
			−12	−74	61	4.23^{p}	37^{2}										
R	Superior Parietal lobule	BA 7	38	−71	33	4.53	45^{2}										
			34	−71	22	3.40^{p}	45^{3}										
L	Inferior Parietal lobule	BA 7/40	−46	−64	47	4.38	12	−43	−60	44	4.17	$125^{**c,3}$					
L	Precuneus	BA 7	−8	−60	68	4.8	37^{1}						−8	−60	68	3.95	20^{1}
R	Precuneus	BA 7											10	−60	64	3.39^{p}	20^{2}
L	Inferior temporal sulcus	BA 37/39						−29	−67	16	4.54	10					
R	Inferior temporal sulcus	BA 37						38	−53	5	3.74	37					
R	Superior temporal sulcus	BA 21/22						38	−53	5	3.74	8					
L	Superior occipital gyrus	BA 19	−36	−84	36	4.44	13^{1}										
			−22	−84	36	3.38^{p}	13^{2}										
Subcortical areas																	
R	Caudate (head)												16	19	2	4.02	17^{1}
R	Caudate (head)		13	9	5	5.66	9						13	9	5	3.68	17^{2}
L	Putamen												−29	−1	−9	4.08	14
<u>XSt versus St</u>																	
Decreased brain activation																	
Cortical areas																	
L	Parahippocampal gyrus	BA 19/37	−36	−43	2	5.55	11										
L	Anterior cingulate gyrus	BA 24	−1	19	16	3.45^{p}	8										
L	Parietal operculum							−40	−12	19	3.67	12					
R	Parietal operculum							55	−1	12	3.46	9					
Subcortical areas																	
L	Caudate (head)							−15	26	16	6.00^{**p}	29	−15	26	16	3.56	9
R	Putamen							27	−29	12	3.84	10					
L	Thalamus (Dorsalmedial nucleus)							−1	−12	8	3.87	44^{1}					
R	Thalamus (Dorsalmedial nucleus)							6	−15	19	3.72	44^{2}					
L	Thalamus (Ventrallateral nucleus)							−18	−19	16	3.56	11					
R	Thalamus (Ventrallateral nucleus)							13	−29	19	3.68	44^{3}					
<u>XSt versus NSt</u>																	
Increased brain activation																	
Cortical areas																	
L	Orbito frontal gyrus	BA 11	−32	37	−2	3.92	16				N.S.					N.S.	
Subcortical areas																	
R	Caudate (head)		10	12	2	6.05	17				N.S.					N.S.	
<u>XSt versus NSt</u>																	
Decreased brain activation																	
Cortical areas																	
L	PreCentral gyrus	BA 4	−26	−22	61	4.32	29^{1}				N.S.					N.S.	
			−32	−26	50	4.06	29^{2}										
L	PostCentral gyrus	BA 2	−32	−36	64	3.87	29^{3}										
R	Superior temporal gyrus	BA 22	66	−5	8	4.42	9										
L	Calcarine sulcus	BA 17	−15	−74	12	3.97	12^{1}										
L	Cuneus	BA 18	−12	−81	19	3.08ˆp	12^{2}										
Subcortical areas																	
	N.S.																

Notes: DID = dissociative identity disorder; dDID = diagnosed DID participants; sDID = simulated DID controls; HC = healthy controls; N.S. = not significant. (X, Y, Z) = MNI coordinates in mm; L/R = Left/Right side of the brain; BA = Broadmann area; St = trauma-avoidant identity state self-relevant trauma-related words;

XSt = trauma-related identity state self-relevant trauma-related words; NSt = trauma-avoidant identity state non-self-relevant trauma words; kE = cluster size in voxels (one voxel is 26262 mm); T = t-value statistic.
x = Extends into the Superior and Inferior Parietal lobule [1]; = first peak voxel [2]; = second peak voxel [3]; = third peak voxel.
**[c] = 0.05 corrected for multiple comparisons at cluster level; [c] = clustersize obtained [p] = 0.005 uncorrected; **[p] = 0.05 corrected for multiple comparisons at peak level; *[p] = also at 0.001 uncorrected for multiple comparison at peak level; [p] = only at 0.005 uncorrected for multiple comparison at peak level.

control group.

We hypothesised that diagnosed DID's trauma-avoidant identity state would show different neural and behavioural responses to the XSt words as compared to St and NSt words. For the behavioural measures, we hypothesised faster reaction times for XSt compared to St and faster reaction times for XSt compared with NSt (for rationale see supplementary materials part 2). For the neural correlates of inter-identity amnesia we hypothesised the involvement of the middle and superior frontal regions as well as the intra-parietal sulci and superior parietal regions, including the precuneus (Reinders et al., 2003, 2014). As compared to the control groups, we expected an effect of group, such that the diagnosed DID group will have the slowest reaction times overall and engage different brain regions compared to the simulating and healthy control groups.

2. Methods

2.1. Participants

This study is the core of a larger neuroimaging project (Chalavi et al., 2015a, 2015b; Strouza et al., 2023; Vissia et al., 2016, 2022) that had the aim to study autobiographical knowledge processing in the brain. In the current study, three groups were included: women with a DSM-IV diagnosis of DID (diagnosed DID; n = 14), healthy DID simulating controls (simulated DID; n = 16), and a group of healthy controls (HC; n = 16). Only women with DID volunteered to participate in this study. The participants were carefully matched for gender, age, education level, and Western European ancestry. Participant and subjectively reported identity state characteristics, simulation instructions and paradigm, in- and exclusion criteria and co-morbid disorders and limited medication effects have been described in detail before (Chalavi et al., 2015b; Dimitrova et al., 2021; Reinders et al., 2018, 2019; Vissia et al., 2016, 2022). Therefore, only a brief summary is provided in the supplementary materials part 3. Of note, in the current paper we do not use the previously applied phrasing "neutral identity state (NIS)", but instead utilize the term "trauma-avoidant identity state", which was first introduced in full in Huntjens et al. (2016).

2.2. Materials and procedure

Materials and procedures are visualised and further explained in Fig. 1 (representing word selection during the first visit) and Fig. 2 (representing the fMRI session during the second visit). Additionally, full details can be viewed in part 2 of the supplementary materials.

Participants visited the research centres in either Amsterdam or Groningen twice. During the first visit they rated 278 Dutch words, in

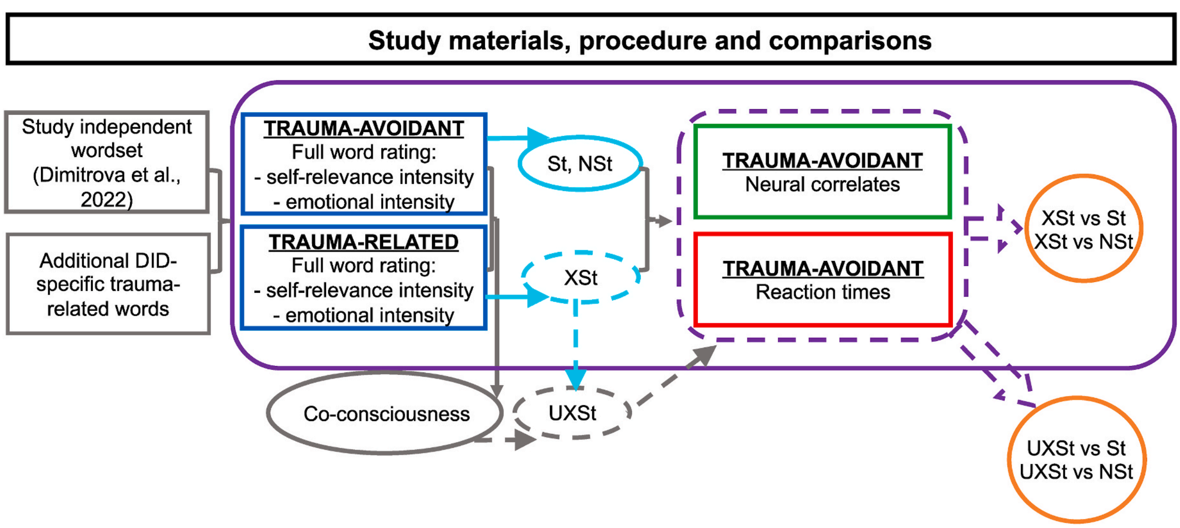

Fig. 1. Study materials, procedure and comparisons
Words – left panel: To obtain subject-specific words participants rated a list of 278 words in an independent session on average 6 weeks before the fMRI session (left panel); words were derived from Dimitrova et al. (2020) (for a full list see Strouza et al., 2023). In the current study the self-relevant trauma-related words and non-self-relevant trauma-related words (St and NSt respectively, presented as cyan in the figure) of the trauma-avoidant identity state were used during the fMRI session were neural activation and behavioural measures were obtained (see dashed purple and green and red blocks in the figure). To investigate the concept of inter-identity amnesia we presented the St words from the trauma-related identity state to the trauma-avoidant identity state during the fMRI scanning session (XSt, dashed cyan in the figure); for more detail on the comparisons see supplementary materials part 1).
Unique words – middle panel: Participating individuals with DID were in phase II of treatment which includes treating trauma-related memories. This means that we had to account for possible co-consciousness of trauma-related memories from the trauma-related identity state by the trauma-avoidant identity state. To confirm if co-consciousness was indeed a factor, we investigated the XSt words in terms of uniqueness to the trauma-related identity state (UXSt, dashed grey in the figure); unique words were only rated as self-relevant and trauma-related in the trauma-related identity state and not the trauma-avoidant identity state. Full methods and results for the analyses that include the unique words are provided in the supplementary materials part 4.
Word comparisons – right panel: Two comparisons were performed to assess inter-identity amnesia. The first comparison tested XSt versus St to see if there is a difference in reaction time and brain activation between trauma-related identity state self-relevant trauma-related words and trauma-avoidant identity state self-relevant trauma-related words. The second comparison tested XSt versus NSt to investigate whether there is a difference in processing between trauma-related identity state self-relevant trauma-related words and trauma-avoidant identity state non-self-relevant trauma-related words in the trauma-avoidant identity-state.
Key: St = trauma-avoidant identity state self-relevant trauma-related words; XSt = trauma-related identity state self-relevant trauma-related words; NSt = trauma-avoidant identity state non-self-relevant trauma-related words; UXSt = unique XSt words.

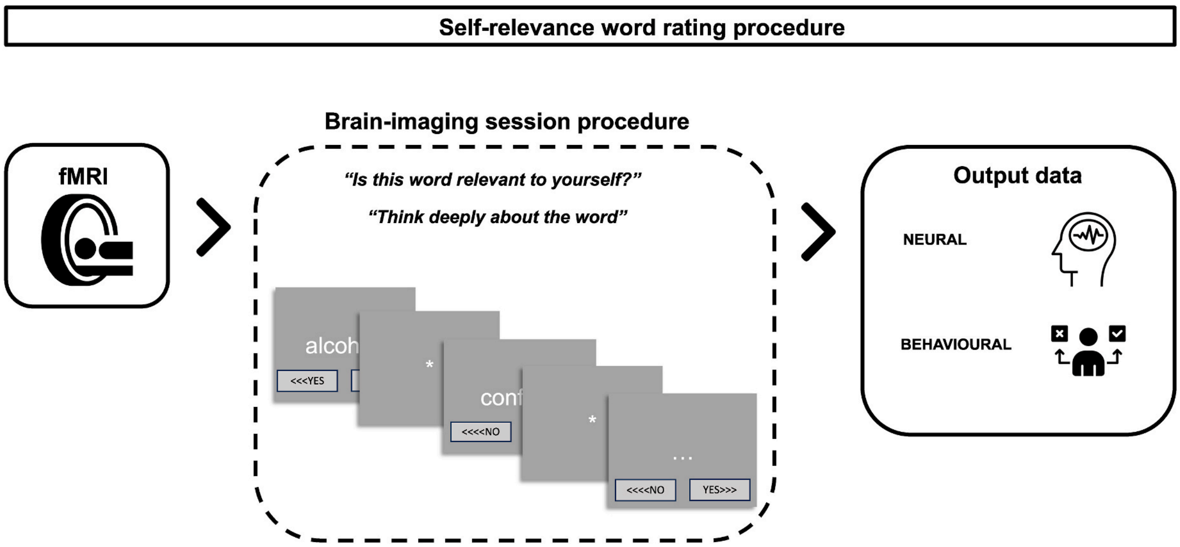

Fig. 2. Self-relevance word rating procedure

To study personal autobiographical memory, Neural and Behavioural data were acquired in two sessions while participants were lying down in the functional magnetic resonance imaging (fMRI) scanner. Participants completed the task approximately two-weeks, on average 6 weeks (mean = 6.36, standard deviation = 5.93), after the initial rating of the words (see Fig. 1). During this brain imaging session, participants were asked to think deeply whether words were self-relevant or not and they responded via a button-box. The word subject to rating would appear in the centre of the screen for up to 5 s, or until the *Presentation* programme logged a response. Following each word slide was a focus slide showcasing an asterisk to maintain the focus of the participants in the centre of the screen. Participants were instructed to answer with their index finger from their left or right hand. The directionality of the response buttons were presented at the bottom of each word screen. Yes/No response button allocation was pseudorandomized to maintain attention, that is, yes/no responses would not be always on the same side. Each trial block contained twenty words and the order in which the trial blocks were presented were equalised across subjects. Although the task was designed to run at the pace of the participant, the maximum duration of each block was up to 25 min. The behavioural data was extracted and transformed using the programme R (version 3.4.1) by A.J.L. for usability with SPSS statistics (IBM SPSS; version 24). For purpose of the current study, we included reaction time and neural data from the trauma-avoidant identity state of both the diagnosed DID and the simulated DID participants and from the HC data and only relevant task conditions were analysed for hypothesis testing.

terms of self-relevance and emotional intensity (see Fig. 1, left panel). The word list (listed in full in Strouza et al., 2023) was based on a pilot study from Dimitrova et al. (2020) and included additional DID-specific trauma-related words (see Fig. 1, left panel). Categories of words that were derived were self-relevant trauma-related words (St) and non-self-relevant trauma-related words (NSt), and to investigate the concept of inter-identity amnesia we crossed over the St words from the trauma-related identity state to the trauma-avoidant identity state during testing. This crossed-over condition is referred to as "XSt". This XSt condition measures inter-identity amnesia for self-relevant trauma-related knowledge, because self-perceived inter-identity amnesia in the trauma-avoidant identity state is for trauma-related knowledge held by the trauma-related identity state. Behavioural and neural data from the trauma-avoidant identity state were acquired while lying down in the fMRI scanner. During this brain-imaging session, the participants were instructed to respond to the three word conditions, namely XSt, St and NSt, with a yes/no response to the question "Is this word relevant to yourself". Both St and XSt represent words that relate to episodic memory in the trauma-avoidant and trauma-related identity states respectively. As part of the decision-making process participants decided if a word was related to personal past events and experiences, reflecting episodic memory. The word rating procedure is visualised and explained in Fig. 2.

Participating individuals with DID were in phase II of treatment, this includes treating trauma-related memories. This means that we had to account for possible co-consciousness of trauma-related memories from the trauma-related identity state by the trauma-avoidant identity state. To confirm if co-consciousness was indeed a factor, we investigated the XSt words in terms of uniqueness to the trauma-related identity state (UXSt, dashed grey in Fig. 1). Unique words were only rated as self-relevant and trauma-related in the trauma-related identity state and not the trauma-avoidant identity state. This "uniqueness" analysis was designed to confirm our main behavioural and neural findings as reported in Table 2. All standard analyses were repeated by employing the alternative post-hoc re-definition of XSt stimuli such that only the XSt words rated "uniquely" self-relevant by the paired identity state were included in the tests (full details on the uniqueness analyses are provided in supplementary materials part 4).

2.3. Data analysis

Two comparisons, that is XSt versus St and XSt versus NSt, for assessing IIA are visualised and detailed in Fig. 1.

2.4. Behavioural data

Within group analyses were conducted using paired-samples t-tests. Two univariate analyses of variance (ANOVAs) were conducted to detect significant descriptive differences in age and years of education between the groups. Repeated measures ANOVAs were then used to examine the effect of word conditions and interaction effects involving the groups. The analyses were performed across the three groups involving the XSt, St, and NSt word conditions. Reaction time of the word conditions were inputted as a factor with 3 levels, while the participant group acted as a between subject factor. Simple contrasts were performed to ascertain the one-tailed direction of the tests, which provide the main analytical outcomes for the outlined hypotheses. Post-hoc p-values were ascertained using Bonferroni's adjustment.

2.5. Neuroimaging data

For acquisition parameters and preprocessing details see supplementary materials part 5. FMRI data were statistically analysed using SPM12 r6906 (Wellcome Trust Centre for Neuroimaging (http://www.

fil.ion.ucl.ac.uk) within Matlab 9.2.0. The general linear model was used for statistical analyses employing a blocked event-related design (Friston et al., 2007). At the subject-level, a boxcar regressor, mapped to the onset and offset of stimulus presentation, was convolved with the canonical haemodynamic response function. For each of the two task sessions, one effect of no interest and three effects of interest were modelled. Furthermore, one session-independent effect of no interest was modelled giving a total of nine regressors. Image volumes containing parameter estimates for two contrasts relevant for the present investigation were calculated and taken to the second level analysis. At the second level, both within-group one-sample t-tests and between-group pairwise independent samples t-tests were conducted to compare the genuine DID group with control groups (i.e., diagnosed DID vs. simulated DID, diagnosed DID vs. HC) on these contrasts and so address our hypotheses. Finally, all analyses were repeated employing the alternative post-hoc re-definition of XSt stimuli such that only the XSt words rated "uniquely" self-relevant were used (for rationale and more information see supplementary materials part 4).

Brain regions surviving a significance level of $p < 0.05$, family-wise error (FWE) multiple comparisons corrected for the whole brain were reported. In addition, brain areas at an explorative threshold of $p < 0.005$ uncorrected were reported (as in Reinders et al., 2016, 2012, 2006) in combination with a voxel extent threshold of ≥ 8 to reduce the risk of Type I error (Petersen and Dubis, 2012). This threshold value was chosen to account for the spatial resolution of the data.

3. Results

3.1. Summary of the main data

Descriptive statistics for the group are presented in Table 1. The participants did not differ significantly on either age or education.

3.2. Behavioural and brain imaging correlates of inter-identity amnesia

Reaction times of the trauma-avoidant identity state to the three conditions, that is, self-relevant trauma-related words (St), self-relevant trauma-related words from the trauma-related identity state (XSt), and non-self-relevant trauma-related words (NSt) are presented in Table 1. Table S1 presents the results after the correction for co-consciousness.

Fig. 3 and Table 2 present the results of the brain imaging data analyses. Table S2 presents the results after the correction for co-

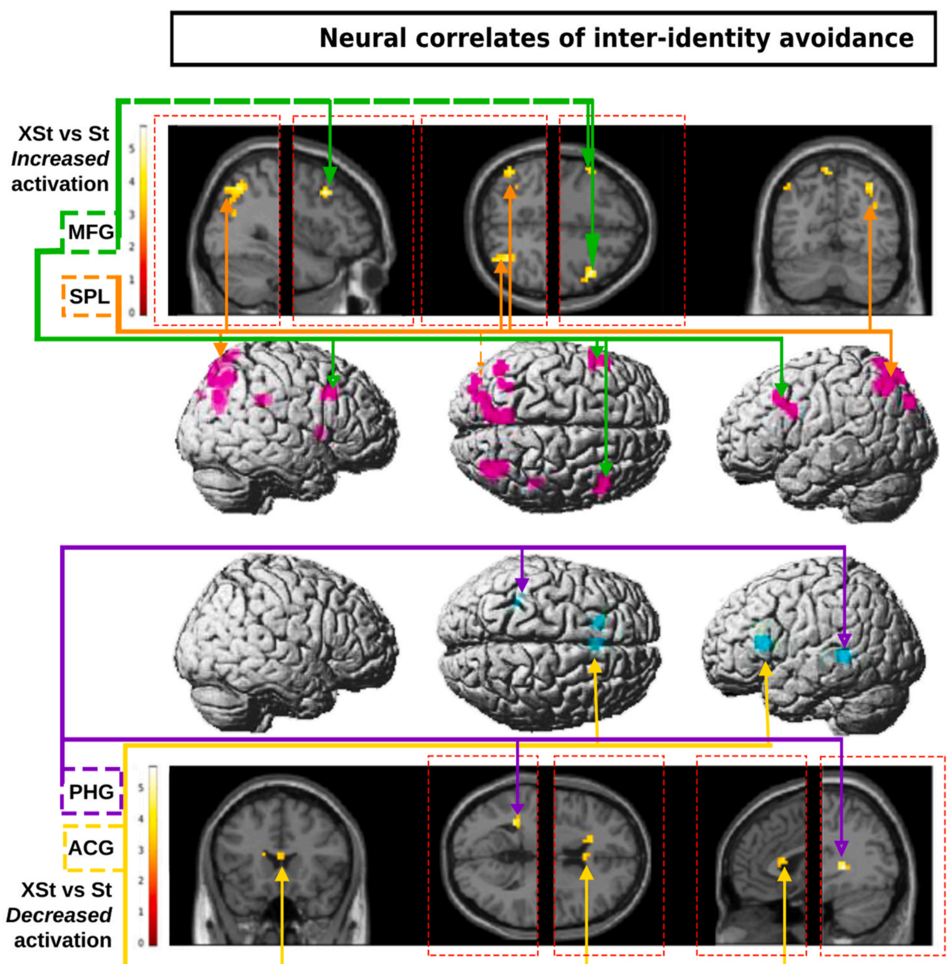

Fig. 3. Neural correlates of inter-identity avoidance
This figure depicts the core findings of the paper, that is, brain activation patterns in response to evaluating self-relevant knowledge in the trauma-avoidant identity state of individuals with DID. The top part of the figure shows increased brain activation when this identity state evaluates self-relevant trauma-related words from the trauma-related state as compared to their own self-relevant trauma-related words. Different parts of the brain are presented and squared off in red to emphasise the best anatomical presentation of a regional activation that is listed in Table 2. In the top part the bilateral activation in the middle frontal gyrus (MFG) and the superior parietal lobule (SPL) is shown. These regions include the peak coordinates listed in Table 2, for the MFG [44, 19, 36] and for the SPL [34, −71, 33]. Decreased activations depicted in the bottom part of the figure are the parahippocampal gyrus (PHG) and anterior cingulate gyrus (ACG). These regions include the peak coordinates listed in Table 2, for the PHG [-36, −43, 2] and for the ACG [-1, 19, 16].

consciousness. Results described next will indicate whether the original results/regions are upheld after the correction for co-consciousness (for results see table S2).

3.3. XSt versus St

3.3.1. Within group

The results of the behavioural data analysis for the diagnosed DID group showed no significant difference in reaction time, whereas the simulated DID and HC groups showed slower reaction times for XSt compared to St words.

The neural data showed that DID's trauma-avoidant identity state responded to the XSt words as compared to their own St words with an increase in cortical regional activation in the left inferior frontal gyrus, dorsolateral prefrontal cortex, bilateral middle frontal gyrus, bilateral intra-parietal sulcus, bilateral superior parietal lobule, left inferior parietal lobule, the left precuneus and left superior occipital gyrus. For the subcortical areas there was an increase in the right head of the caudate. There was a decrease in activation in the left parahippocampal gyrus and the left dorsal anterior cingulate gyrus. Similar results were obtained after correcting for co-consciousness (see table S2).

3.4. Between groups

3.4.1. Diagnosed DID versus HC

The between group analyses of the behavioural data from the diagnosed DID group versus the HC group did not show any significant differences in reaction time.

The neural data showed increases for the diagnosed DID group as compared to the HC group in regional brain activation for XSt as compared to St for the following regions: right superior frontal sulcus, bilateral middle frontal gyrus, the left precentral gyrus, bilateral intra-parietal sulcus, left superior parietal lobule, left inferior parietal lobule, bilateral inferior temporal sulcus, and the right superior temporal sulcus. Decreases in activation were found in the bilateral parietal operculum, left caudate head, the right putamen, and bilateral dorsomedial nucleus, and the ventrolateral nucleus of the thalamus. Similar results were obtained after correcting for co-consciousness (see table S2).

3.4.2. Diagnosed DID versus simulated DID

The between group analyses of the behavioural data from the diagnosed DID versus the simulated DID showed no significant differences in reaction times.

The neural data showed an increase in activation for XSt in the diagnosed DID group as compared to the simulated DID group in the left middle frontal gyrus, bilateral precuneus, the right caudate head, and the left putamen. There was a decrease in activation in the left caudate head. Similar results were obtained after correcting for co-consciousness (table S2).

3.5. XSt versus NSt

3.5.1. Within group

The results of the behavioural data analysis for the diagnosed DID and simulated DID groups showed no significant differences in reaction times, whereas the HC group showed slower reaction times for XSt compared to NSt words.

The neural data showed that the trauma-avoidant identity state responded to XSt as compared to their own NSt words with increased brain activation in the left orbitofrontal gyrus and the right caudate head. Decreases in activation were found in the left precentral gyrus, left post central gyrus, the right superior temporal gyrus, the left calcarine sulcus, and the left cuneus. Similar results were obtained after correcting for co-consciousness (table S2).

3.6. Between groups

3.6.1. Diagnosed DID versus HC

The analyses of the behavioural data between the diagnosed DID and the HC group showed a significant difference in reaction times between XSt and NSt in favour of quicker reaction times for XSt over NSt ($F(2,40) = -3{\cdot}819$, $p = 0{\cdot}030$, $\eta_p^2 = 0{\cdot}160$), with a mean difference of $-0{\cdot}114$ quicker reaction time for diagnosed DID on XSt.

The analyses of the brain activation data between the diagnosed DID and the HC group did not reveal any significant differences.

3.6.2. Diagnosed DID versus simulated DID

The analyses of the behavioural data of the diagnosed DID versus the simulated DID showed no significant differences in reaction times.

The between group analyses for the brain activation data did not show any significant differences between diagnosed DID and simulated DID.

4. Discussion

This is the first study to jointly investigate the behavioural and neural correlates of inter-identity amnesia for trauma-related knowledge in individuals with dissociative identity disorder (DID). Our most important finding is the independent reproduction of the majority of brain regions previously proposed to facilitate subjective inter-identity amnesia (Reinders et al., 2003, 2014). Our second most important finding is that the behavioural measures did not support the notion of inter-identity amnesia and are thereby in line with previous behavioural studies (Huntjens et al., 2006, 2012, 2016; Reinders et al., 2022). We therefore propose a novel explanation and terminology for self-perceived amnesia in DID and to redefine this phenomenon to "inter-identity avoidance".

We propose the idea that individuals with DID implement neural mechanisms of cognitive control that serve to mentally avoid self-relevant processing of trauma-related knowledge to protect against emotional hyperarousal and enable normal daily functioning. In line with Reinders et al.'s (2012) statement that for "NIS' "mental avoidance (Nijenhuis et al., 2002) of unwanted memories in DID the *posterior association areas (PAA)*[2] fulfils a pivotal role", we put forward that the neural mechanisms of cognitive control to implement inter-identity avoidance include increased activation in the intra-parietal sulci and inferior/superior parietal regions, which includes the precuneus, as well as the dorsolateral prefrontal and middle frontal regions in response to XSt as compared to St words. Most of these activated brain regions were confirmed in the post-hoc analyses where we corrected for co-consciousness between identity states as presented in detail in the supplementary materials part 4 and table S2. Our results are further supported by independent research which has shown that cognitive control is maintained through the simultaneous activation of regions in the frontal and parietal cortices, namely the dorsolateral prefrontal cortex (dlPFC) and dorsal/posterior parietal cortex (d/pPC) making up the frontoparietal network (Dosenbach et al., 2008; Niendam et al., 2012). This frontoparietal network has also been shown in complex PTSD where patients display an increased activation in brain regions in the context of trauma-related words associated with cognitive control, that is dlPFC, vmPFC, and dorsal anterior cingulate cortex (dACC) (Breukelaar et al., 2017). Lebois et al. (2021) has shown that the frontoparietal and default mode networks[3] activate simultaneously for autobiographical cues in relation to dissociative symptom severity; this implies an internal reorientation of cognitive attention during self-referential processing, that is, a heightened cognitive control over self-relevant processing of memories. In our study, we maximised the

[2] Abbreviations expanded and italics added.

[3] For more information on default mode network see supplementary part 6.

trauma-related trigger by giving trauma (XSt) words from the trauma-related state to the trauma-avoidant state, and confirmed previously specified brain activation pattern (Reinders et al., 2006).

The increased activation of the frontal regions in the diagnosed DID group imply a protective inhibitory function (that is cognitive control) in the development of emotion regulation, the development of the self, and experience-dependent maturation of the orbitofrontal cortex (Forrest, 2001). The orbitofrontal cortex also plays a critical role in the development of 'distinct mental states', that is, it has an inhibitory function which contributes to avoidant, dissociated states (Putnam, 1997). We found an increase in activation in the orbitofrontal gyrus for XSt compared to NSt, our second study comparison, suggesting a stronger active inhibition of processing to XSt words. In addition, we found hypoactivation of the dACC in response to XSt versus St. The dACC has been linked to cognitive control and self-regulation (Posner et al., 2007) and it has been suggested that altered activity in those regions contributes to a preservation of self-function, that is, going through life on a day to day basis despite being presented with triggering self-relevant material (Qin et al., 2010).

Coinciding with these frontal regions we found increased activation in both inferior and superior parietal regions, as well as in the precuneus and the inter-parietal sulcus. Parietal regions have emerged from studies into dissociative pathology with a frequency of findings comparable to those of the frontal regions (see for review Roydeva and Reinders, 2021). These two brain regions are core in the frontoparietal network which initiates and adjusts cognitive control and inhibits emotional affect (Dosenbach et al., 2008). As such, finding the activation of this network in the current study is not surprising because it implies the importance of cognitive control of trauma-related knowledge in DID, lending strength to the role of the parietal cortex in pathological dissociation. It is also important to note that the brain activation patterns found in the current study are consistent with previous studies regarding inter-identity control of trauma-related knowledge (Reinders et al., 2014; Roydeva and Reinders, 2021; Şar et al., 2007). In light of the current reproducibility crisis for brain imaging data (see Marek et al., 2022) and DID-related discussion (Reinders et al., 2022), our results are important because they reproduce previous findings (see for example Reinders et al., 2014, 2003) in an independent sample while using a different brain imaging technique.

Our second most important finding is that our behavioural data supports conclusions from previous studies, namely that there is no evidence for compartmentalisation of trauma-related knowledge and for inter-identity amnesia (Reinders et al., 2022). It is important to note that previously it has been argued that inter-identity amnesia was only evident for subject specific trauma-related material (Nijenhuis et al., 2019; Reinders et al., 2022). As it turns out, we have now provided evidence which rejects this hypothesis and suggests a transfer of knowledge between identity states in diagnosed DID participants that was not simulated in our DID simulating control group. This is further supported by our uniqueness analyses in which we also found no difference in reaction times in diagnosed DID only. At the same time the behavioural data in our study show different behavioural responses to XSt and NSt, with quicker reaction times for XSt. This suggests recognition of the XSt word stimuli while engaging the frontoparietal cognitive control network, including increased orbitofrontal gyrus activation (see Table 2) to prevent the self-relevant processing of this knowledge. This finding underlines the importance of autobiographical knowledge as a precursor for inter-identity control and cognitive avoidance of trauma-related knowledge (Nijenhuis et al., 2019). This is further supported by current theoretical work that self-perceived amnesia is achieved as a result of metamemory deficits in monitoring autobiographical experiences (Dorahy, 2022). Self-relevance knowledge is accessible but when such knowledge is trauma-related, cognitive control prevents accessibility. Taken together, we propose that there is inter-identity *avoidance* rather than amnesia, mediated by a frontal-parietal neural network enabling cognitive control of self-relevant processing of trauma-related knowledge.

The findings of this study have important implications for DID in the clinical realm and for future research. Treatment of DID should focus on emotion regulation to develop grounding and safe stabilisation and before working with the barriers an individual has to reduce their cognitive avoidance of traumatic material. In addition, repetitive transcranial magnetic stimulation on the key nodes of the frontoparietal network could be considered (Roydeva and Reinders, 2021). Similarly, neurofeedback has been shown to normalise PTSD default mode network activity and emotion regulation through resynchronisation of alpha power over regions including the dorsomedial prefrontal cortex (Kluetsch et al., 2014; Nicholson et al., 2023), which implies an interest to extend this research to DID. Furthermore, we highlight the importance of incorporating both trauma-related and avoidant identity states and especially of using a multimodal approach when researching DID because our results showcase that behavioural measures only are not sufficient in informing on the complex processes involved in the brain in individuals with DID and need to be evaluated in the context of neural activation. Finally, our results reproduce many of the brain biomarkers put forward by previous literature (Reinders et al., 2006), lending further support to distinct pathological dissociation neurobiological frameworks, cementing DID as a trauma-based disorder.

With regards to limitations of our study, although the number of participants is similar to other studies in the field, the group size limits statistical power to detect small effects. However, this is partly compensated by the specificity of the stimuli which is a key strength of this study's design and pertains to its unique use of participant-generated self-relevant wordlists which engages individual processing, enabling a (statistically) stronger investigation into inter-identity for each participant with DID. Despite the relative low number of participants and liberal explorative threshold it is important to note that many of the brain areas found have been reported before in an independent sample of individuals with DID (Reinders et al., 2006, 2012, 2014), a systematic review (Roydeva and Reinders, 2021), and we have found task-specific activation patterns at the same statistical threshold in the current sample for a working memory task (Vissia et al., 2022), supporting the authenticity of our findings.

In conclusion, our study reproduces and amalgamates previously reported results of behavioural and neural activation data in an independent sample of individuals with DID. Instead of the idea of compartmentalisation of traumatic knowledge we propose a heightened cognitive control and inter-identity avoidance of trauma-related knowledge. By confirming the frontoparietal network involvement in dissociative pathology we advance the understanding of its neural mechanisms.

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CRediT authorship contribution statement

Lora I. Dimitrova: Writing – review & editing, Writing – original draft. **Andrew J. Lawrence:** Writing – review & editing, Formal analysis, Data curation. **Eline M. Vissia:** Writing – review & editing, Methodology, Data curation. **Sima Chalavi:** Writing – review & editing, Writing – original draft, Data curation. **Andreana F. Kakouris:** Writing – original draft. **Dick J. Veltman:** Writing – review & editing, Supervision. **Antje A.T.S. Reinders:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Data curation, Conceptualization.

Declaration of competing interest

None

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Appendix ASupplementary data

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