



# Individuals with psychotic-like experiences exhibit enhanced involuntary autobiographical memories

Mélissa C. Allé<sup>a,\*</sup>, Fabrice Berna<sup>b</sup>, Dorte Berntsen<sup>a</sup>

<sup>a</sup> Center on Autobiographical Memory Research, Department of Psychology and Behavioural Sciences, Bartholins Allé 11, Aarhus University, Aarhus C 8000, Denmark

<sup>b</sup> Inserm U1114, Strasbourg University, University Hospital of Strasbourg, France



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## ABSTRACT

The relationship between hallucinations and stressful life events in psychosis is recognised, and has recently been supported by findings showing that the frequency of involuntary autobiographical memory and future projection predicts hallucination-proneness in the general population. To better understand the nature of this relationship, an online survey was conducted in 44 individuals with high Psychotic Like Experiences (PLE) and 44 matched controls, assessing the quantitative, qualitative and content characteristics of their involuntary autobiographical memories and future thoughts. Individuals with high PLE displayed a higher frequency of both involuntary autobiographical memory and future thought compared to controls. Moreover, the associated emotional intensity, feeling of reliving and intrusiveness were increased. Contrary to controls' memories, involuntary memories of individuals with high PLE more frequently referred to traumatic events and were associated with negative mood impact at retrieval. Taken together, these results can be seen as consistent with a relationship between involuntary memory and hallucination, by suggesting phenomenological and content related similarities between the two processes.

## 1. Introduction

Involuntary autobiographical memories and future thoughts are spontaneously arising memories of personal events or imagined future events (Berntsen, 2010; Berntsen and Jacobsen, 2008; Finnbogadóttir and Berntsen, 2011), in distinction to their voluntary counterparts, that is the strategic retrieval (or imagination) of personal events. Such involuntary mental time travel results from automatic and associative processes, with little cognitive control (Hall et al., 2014). The phenomenological characteristics of involuntary autobiographical memory and future thought generally vary across individuals (Berntsen et al., 2015), and are altered in several clinical conditions. For instance, in post-traumatic stress disorder (PTSD), they have been described as being more vivid and distressing, and associated with stronger emotional reactions (e.g., Berntsen and Rubin, 2015; Rubin et al., 2008, 2011).

Neutral and stress-related involuntary autobiographical memories have been shown to be more frequent throughout the psychosis continuum (i.e., in both individuals with attenuated psychotic symptoms or psychotic disorder; Allé et al., 2018; Holmes and Steel, 2004; Jones and Steel, 2012, 2014). Recently, enhanced frequency and emotional intensity of involuntary autobiographical memories and future

projections were shown to predict hallucination-proneness in the general population (Allé et al., 2018). This relationship between involuntary mental time travel and hallucination was found to be robust, even when controlling for personality traits, clinical symptoms (depression and dissociation) and cognitive functioning.

Hallucination—that is, perceptual experience that occurs in the absence of a corresponding external stimulation—is one of most common symptoms of psychosis, as 70% of patients with schizophrenia report such experiences (van Os et al., 2009). In addition, about 4% of the general population also experience this phenomenon, without any mental condition (van Os et al., 2009). Over the last decades, there has been growing interest in the contribution of traumatic events to the development of hallucinations in psychosis (e.g., Cole et al., 2016; Hardy et al., 2005; Steel, 2015), assuming a particular role to autobiographical memory (McCarthy-Jones et al., 2014). Phenomenological observations have shown that 13% of patients with psychosis reported hallucinations with content similar to past trauma, and 45% reported hallucinations in which the theme of trauma was common (Hardy et al., 2005).

These clinical observations are reinforced by several cognitive memory-based models of hallucination. Because of two acknowledged deficits, auditory hallucination in psychosis can result from

\* Corresponding author.

E-mail address: [melissa@psy.au.dk](mailto:melissa@psy.au.dk) (M.C. Allé).

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unintentional (i.e., involuntary) activation of decontextualized memories of prior events (Hemsley, 2005; Waters et al., 2006). First, inhibitory failures would lead to mental representations of these memories intruding into consciousness (Soriano et al., 2009). Second, the deficit of contextual information would result in an inability to form a complete representation of the origins of the memories, which are thus less easily recognized as memories (Badcock et al., 2007). In addition, so-called traumatic-psychosis models emphasize that a specific category of auditory hallucinations are rooted in traumatic memories, largely due to contextual integration deficits (Hardy et al., 2005; Steel et al., 2005; Steel, 2015).

In summary, phenomenological observations, theoretical models and experimental findings have provided important insights into the role of autobiographical memory in hallucination in psychosis. Previous studies have mainly focused on the frequency of experiencing involuntary autobiographical memories. Allé et al. (2018) showed that higher frequency of involuntary mental time travel strongly predicted hallucination-proneness in the general population. Yet, the qualitative characteristics and content of involuntary autobiographical memories have remained unexplored in the psychosis continuum.

The aim of the present study is to explore more deeply the relationship between involuntary mental time travel and hallucination in the psychosis continuum, by investigating whether non-clinical individuals with elevated Psychotic-Like Experiences (PLE), compared with control participants, display different involuntary autobiographical memories and future projections in terms of both their experienced frequency, quality and content.

A first series of hypothesis was made on the basis of previous work on the experienced frequency of involuntary and voluntary mental time travel. We hypothesized (1) that mental time travel (i.e., both memories and future projections) would be more frequently experienced in individuals with high PLE compared to controls (Allé et al., 2018; Holmes and Steel, 2004; Jones and Steel, 2012), (2) that involuntary future projections would be overall less frequent than involuntary memories (Berntsen et al., 2015) and (3) that involuntary future projections of individuals with high PLE would be even more frequent than their involuntary memories, as they have been hypothesized to strongly relate to hallucination (Allé et al., 2018).

Secondly, we hypothesized that involuntary autobiographical memories of individuals with high PLE would differ from those of controls in terms of phenomenological characteristics and content. Because our theoretical approach is grounded in clinical observations and in traumatic-psychosis models (Steel, 2015), we assumed that involuntary memories of individuals with high PLE would display a similar pattern as those of individuals with PTSD, by being highly vivid, intrusive and associated with a high emotional intensity (Rubin et al., 2008). Consistently, we also hypothesized that involuntary autobiographical memory of individuals with high PLE would refer to past trauma more often than those of controls.

## 2. Methods

### 2.1. Participants

Forty-four individuals with high PLE (19 women and 25 men) and 44 control participants with low PLE (19 women and 25 men) were included in this study.<sup>1</sup> The two groups were matched on age, gender and educational level (see Table 1). All participants were recruited through Amazon's Mechanical Turk. Screening and allocation to the high PLE versus low PLE groups were based on the participants' answers to the Community Assessment of Psychic Experiences

<sup>1</sup> These participants were part of a bigger sample of participants ( $n = 482$ ) in Allé, Berna & Berntsen (2018). However, the present findings have never been reported before.

questionnaire (CAPE; Stefanis et al., 2002; see procedure and Materials, below, for details). The study was approved by the local ethics committee and an informed consent was obtained for each participant. Mechanical Turk workers received USD \$2 for taking part in the study.

### 2.2. Procedure and materials

The study was conducted online using Qualtrics Survey<sup>®</sup> Software, which enables interactive questionnaires to be created and specific populations to be targeted. Participants who did not correctly answer control questions (distributed all along the survey, to make sure the respondents actually read questions before answering), and those who did not fully complete the survey were excluded. To assess PLE and involuntary autobiographical memories, participants filled out various validated psychological and subclinical scales, detailed below.

### 2.3. Community Assessment of Psychotic Experiences (CAPE; Stefanis et al., 2002)

Participants completed the CAPE questionnaire, which assesses PLE and the distress associated with those symptoms. It comprises 42 items scored on a 4-point Likert scale with 1 = *Never*, 2 = *Sometimes*, 3 = *Often*, 4 = *Nearly always*. Items are derived from clinical rating scales but worded in a manner comprehensible to both healthy and clinical populations. Three syndromes are evaluated through the CAPE: positive (e.g., “Do you ever feel as if you are being persecuted in some way?”), negative (e.g., “Do you ever feel that you experience few or no emotions at important events?”) and depressive (e.g., “Do you ever feel pessimistic about everything?”). The internal consistency of this inventory in the current study was excellent (Cronbach's  $\alpha = 0.91$  for frequency of symptoms and Cronbach's  $\alpha = 0.92$  for associated distress).

In research on the psychosis continuum, the CAPE is commonly used to discriminate individuals with high PLE, defined as those individuals who score 1.5 SD above the mean total score (i.e., 1.67 of a maximum of 4.00), versus individuals with low PLE, who score less than 0.5 SD above the mean of CAPE total score (e.g., Berna et al., 2016a; Cicero et al., 2013). Based on this method, 44 of the 482 participants (primary sample) were considered to have high PLE (i.e., CAPE score > 2.40 of a maximum of 4.00). The control group with low PLE was composed of 44 individuals, matched for age, gender and level of education, scoring < 1.91, without a psychiatric history or current antipsychotic medication. Thirty-three of the 44 individuals with high PLE reported a history of psychiatric diagnosis (e.g., depression or anxiety disorder), eight were engaged in psychotherapy and eight reported current medications (see Table 1).

### 2.4. Involuntary Autobiographical Memory Inventory (IAMI; Berntsen et al., 2015)

The IAMI assesses the frequency of involuntary autobiographical memories and involuntary future thoughts in daily life. Each item is rated as: 0 = *Never*; 1 = *Once a month or more*; 2 = *Once a week or more*; 3 = *Once a day or more*; 4 = *Once an hour or more*. The scale describes various daily life situations to evaluate the occurrence of involuntary autobiographical memories or involuntary future thoughts (e.g., “When I am bored, imaginary future events come to my mind by themselves—without me consciously trying to evoke them”; “Listening to some music or songs bring memories of past events to mind – without me consciously trying to remember them”). Mean scores are calculated for involuntary autobiographical memories (10 items), involuntary future thoughts (10 items) and total score (20 items). The internal consistency of this inventory in the current study was excellent (Cronbach's  $\alpha = 0.91$ ).

**Table 1**  
Demographic Characteristics of Individuals with high PLE and Control Participants with low PLE.

Measures	Individuals with high PLE (n = 44)		Control participants with low PLE (n = 44)		Statistics		
	M	SD/%	M	SD/%	t-test	d	95% CI
Age (years)	28.43	7.70	28.84	7.40	-0.25	-0.02	[-3.38, 3.00]
Gender (female)	19.00	43%	19.00	43%			
Level of education	14.36	1.75	14.48	1.59	-0.32	0.00	[-0.80, 0.60]
CAPE frequency total score	2.77	0.28	1.42	0.28	22.50***	4.87	[1.23, 1.47]
CAPE distress total score	2.40	0.36	1.31	0.31	13.50***	2.86	[0.84, 1.36]
<b>Reported lifetime psychiatric diagnoses<sup>a</sup></b>							
No psychiatric diagnosis	11	25%	44	100%			
Schizophrenia	0	0%	0	0%			
Bipolar disorder	6	13.6%	0	0%			
Depression	18	40.9%	0	0%			
Anxiety disorder	13	29.5%	0	0%			
Obsessive-compulsive disorder	3	6.8%	0	0%			
Post-traumatic stress disorder	3	6.8%	0	0%			
Eating disorder	0	0%	0	0%			
Substance/alcohol use disorder	2	4.5%	0	0%			
Reported current psychotherapy	8	18.2%	0	0%			
<b>Reported current medication</b>							
No medication	36	81.8%	44	100%			
Antidepressants	8	18.2%	0	0%			
Tranquilizers	0	0%	0	0%			
Hypnotics	0	0%	0	0%			
Antipsychotics	0	0%	0	0%			
Stimulants	0	0%	0	0%			

Note. PLE = Psychotic Like Experiences; CAPE = Community Assessment of Psychic Experiences; CI = Confidence Interval; LSHS-R = Launay-Slade Hallucinations Scale Revised

<sup>a</sup> Some participants received several psychiatric diagnoses

\*p < 0.05; \*\*p < 0.01

\*\*\* p < 0.001

**2.5. Emotional valence and emotional intensity of involuntary memories and future projections (Berntsen et al., 2015)**

Four items were answered immediately after completing the IAMI, to assess emotional valence and intensity of involuntary autobiographical memory and future thought. Table 2-A shows the question and the rating scale for each item.

**Table 2**

Variable labels, questions and ratings composing the questionnaires for A - involuntary memory and future thought general assessment (Berntsen et al., 2015), and B- examples of involuntary autobiographical memories.

A-Involuntary Memory and Future Thought General Assessment	
(General Emotional Valence of Memories) For the spontaneously arising memories of past events, in general how positive or negative were the memories? From -2 extremely negative, to +2 extremely positive	
(General Emotional Intensity of Memories) For the spontaneously arising memories of past events, in general how emotionally intense were the memories? From 0 not at all intense, to 4 extremely intense	
(General Emotional Valence of Future Thoughts) For the spontaneously arising imaginations of possible future events, in general how positive or negative were the imaginations? From -2 extremely negative, to +2 extremely positive	
(General Emotional Intensity of Future Thoughts) For the spontaneously arising imaginations of future events, in general how emotionally intense were the imaginations? From 0 not at all intense, to 4 extremely intense	
<b>B-Questions for Involuntary Autobiographical Memories Examples</b>	
(Vividness) How vivid is the memory in your mind? From 1 = Very vague to 5 = Clear and very detailed	
(Reliving) Please indicate whether it applies to you. "I feel as though I am reliving it". From 1 = Strongly disagree to Strongly agree	
(Coherence) How is your mental representation of this event? From 1 = My memory comes in pieces, fragments with missing bits to 5 = My memories comes to me as a coherent story	
(Emotional Valence) Was the memory particularly emotional? From 1 = Extremely negative to 5 = Extremely positive	
(Mood Impact) Did this memory affect your mood? Better/Worse/No Impact	
(Intrusiveness) Please indicate whether it applies to you. "I feel that this memory is very intrusive in my mind. It comes to my mind even if I don't want it."	

**2.6. Voluntary control questions (Berntsen et al., 2015)**

Ten questions similar to the IAMI target the frequency of voluntary (intentional) recall of autobiographical memories and future thoughts in various daily life situations. Questions were kept as close as possible to corresponding IAMI questions and were rated on the same frequency scale (0 to 4). Half of the questions are directed toward past and half toward future thinking. The internal consistency of this questionnaire in the current study was high (Cronbach's  $\alpha = 0.84$ ).

**2.7. Assessment of involuntary autobiographical memories characteristics**

To assess the subjective characteristics of involuntary memories, participants were asked to identify and describe two examples of involuntary autobiographical memories they had experienced in their life. Participants answered a series of questions to characterize the qualities of each memory. These questions were derived or modified from previous work (Berntsen and Bohn, 2010; Rubin et al., 2003; Rubin and Berntsen, 2009). Table 2-B shows the question and the rating scale for each item.

Based on participants' descriptions, seven categories of events most frequently and spontaneously recalled were distinguished: (1) major achievements, (2) childhood mundane events, (3) daily life events, (4) missed opportunities, remorse or events that did not happen, (5) failures or humiliations, (6) traumatic or life threatening events, and (7) death related events. The theme of each involuntary memory was also rated by two external coders, with a good inter-reliability ( $\kappa = 0.82$ ). Each disagreement was discussed and resolved.

**3. Results**

**3.1. Involuntary and voluntary autobiographical memories and future projections frequencies**

We conducted a 2 (Group: high PLE versus controls) × 2 (Time:

**Table 3**  
Characteristics of Involuntary Memories in Individuals with high PLE and Control Participants with low PLE.

Measures	Individuals with high PLE (n = 44)		Control participants with low PLE (n = 44)		Statistics		
	M	SD	M	SD	t-test	d	95% IC
General emotional valence <sup>a,c</sup>	0.19	0.81	0.26	0.61	-0.44	-0.06	[-0.34, 0.27]
General emotional intensity <sup>b,c</sup>	3.37	0.78	2.26	0.79	6.66***	1.45	[0.79, 1.45]
<b>Examples of IVM</b>							
Number of memories	1.45	0.79	1.57	0.79	-0.67	-0.15	[-0.29, 0.22]
Vividness <sup>b</sup>	3.76	0.96	3.32	1.14	1.85 <sup>§</sup>	0.48	[-0.03, 0.90]
Coherence of the memory <sup>b</sup>	4.94	1.37	4.36	1.81	1.62	0.38	[-0.13, 1.29]
Reliving <sup>b</sup>	3.47	0.95	2.92	1.31	2.16*	0.52	[0.04, 1.06]
Emotional Valence <sup>b</sup>	3.60	1.73	4.05	1.55	-1.23	-0.28	[-1.19, 0.28]
Intrusiveness <sup>b</sup>	3.43	1.08	2.47	1.35	3.49***	1.19	[0.41, 1.50]

Note. PLE = Psychotic Like Experiences; IVM = Involuntary Autobiographical Memories

<sup>a</sup> rated from -2 to + 2

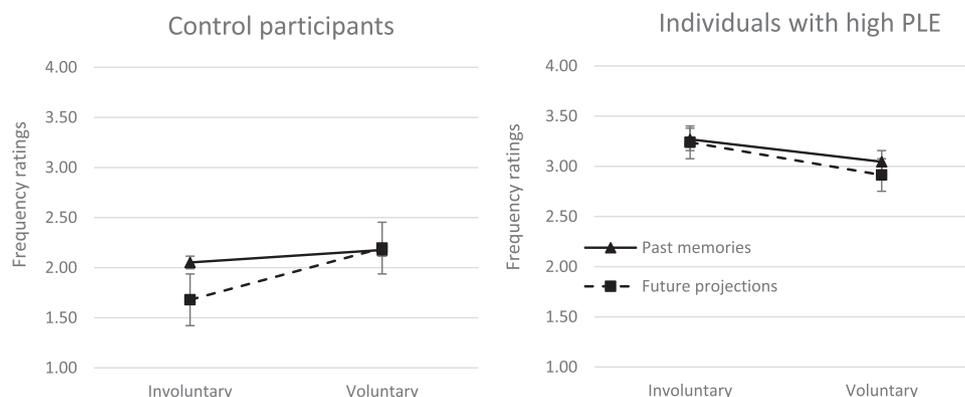
<sup>b</sup> rated from 1 to 5

<sup>c</sup> for both memories and future thoughts

<sup>§</sup> p < 0.10

\* p < 0.05; \*\*p < 0.01

\*\*\* p < 0.001



**Fig. 1.** The mean frequency ratings of involuntary and voluntary autobiographical past memories versus future projections among individuals with high PLE versus control participants with low PLE.

past versus future) × 2 (Retrieval type: involuntary versus voluntary control questions) repeated measures ANOVA, with Time and Retrieval type as repeated measures factors and Group as a between subjects variable (see Fig. 1). There was a main effect of group, with the high PLE group having overall higher scores,  $F(1, 83) = 103.08; p < 0.001; \eta_p^2 = 0.55$ . There was also a main effect of time, with past being rating higher than future,  $F(1, 83) = 8.16; p = 0.005; \eta_p^2 = 0.09$ . No effect of Retrieval type was observed,  $F(1, 83) = 1.72; p = 0.19; \eta_p^2 = 0.02$ . Two interactions were also observed. There was a two-way interaction between Retrieval type and Group  $F(1, 83) = 7.94; p = 0.006; \eta_p^2 = 0.09$ , reflecting that the high PLE group had equivalent frequency ratings for involuntary and voluntary scales,  $t(44) = 1.11, p = 0.27, d = -0.34$ , whereas the control group had lower frequency ratings for involuntary past and future events  $t(44) = 2.82, p = 0.007, d = 0.87$ . No interaction was found between Time and Group or Retrieval type and Time,  $F(1, 83) < 1.87; ps > 0.18; \eta_p^2 < .002$ . Importantly, a three-way interaction was observed between Retrieval type, Time and Group,  $F(1, 83) = 9.35; p = 0.003; \eta_p^2 = 0.10$ , reflecting that involuntary future projections were less frequent than all other three categories of mental events in control participants ( $ps < 0.001$ ), whereas a different pattern was observed for individuals with high PLE. Here, involuntary past and future events were both rated as more frequent than their voluntary counterparts ( $ps < 0.03$ ). Thus, individuals with high PLE scored higher on both the IAMI and voluntary control questions compared with controls. This difference was most pronounced for the IAMI scores and especially so for the subscale for involuntary future projections (see Fig. 1).

**3.2. Emotional valence and emotional intensity of involuntary memories and future projections (see Table 3)**

Emotional valence of involuntary memories and future projections overall were rated equally by both groups ( $p = 0.66$ ) whereas their emotional intensity was significantly higher in individuals with high PLE than controls ( $p < 0.001$ ).

**3.3. Involuntary autobiographical memories characteristics (see Table 3)**

Individuals with high PLE were able to describe as many involuntary autobiographical memories as controls ( $p = 0.55$ ), when asked to give two examples of involuntary memories experienced. Involuntary autobiographical memories did not differ in terms of coherence or emotional valence between groups ( $ps > 0.11$ ). The vividness of high PLE individuals' involuntary memories was higher than for controls, although not significantly ( $p = 0.07$ ). The degree of reliving and the intrusiveness of involuntary memories were both higher in the high PLE group compared with the control group with low PLE ( $ps < 0.03$ ). Vividness, reliving, intrusiveness correlated highly with each other ( $rs > 0.37; ps < 0.001$ ) suggesting they should be regarded as related aspects of the experience of involuntary recollections, consistent with the fact that they should the same pattern regarding mean differences.

The impact of involuntary memories on mood differed according to group. Involuntary memories had substantially more negative mood impact for individuals with high PLE (for 63.08% of memories) than for

**Table 4**  
Percentages of Involuntary Autobiographical Memories for Each Content Category in Individuals with high PLE and Control Participants with low PLE.

Content Category	Individuals with high PLE (n = 44)	Control participants with low PLE (n = 44)	Statistics Chi Square	p-value
Life threatening event	32.2	5.17	9.00	.003
Major achievement	18.64	12.07	0.59	.44
Fail/humiliation	16.95	18.97	0.27	.60
Daily life event	10.17	18.97	1.33	.25
Missed opportunities/remorse	6.78	1.72	1.00	.32
Other	6.78	8.62	0.58	.44
Death	5.08	8.62	0.67	.41
Childhood event	3.39	25.86	8.33	.004

Note. PLE = Psychotic Like Experiences.

control participants (23.19% of memories),  $\chi^2 = 25.20$ ;  $p < 0.001$ .

Finally, the content of involuntary memories was also significantly different between groups,  $\chi^2 = 18.18$ ;  $p = 0.02$ . Individuals with high PLE spontaneously recalled more memories related to past trauma than control participants did, but fewer childhood mundane events or daily life events (see Table 4).

#### 4. Discussion

This study investigated involuntary autobiographical memory and future thought in individuals with high PLE. The main findings comprised higher frequencies of both voluntary and involuntary autobiographical memories and future thoughts in individuals with high PLE, reproducing previous observations of higher frequencies of involuntary memories or intrusive thought in the psychotic continuum (Holmes and Steel, 2004; Jones and Steel, 2012). Importantly, the results extended previous findings by showing that in addition to highly frequent involuntary memories, individuals with high PLE experience several aspects of the mental time travel more frequently (voluntary and involuntary autobiographical memories and future thoughts), similarly to individuals with high levels of PTSD symptoms (Rubin et al., 2008). This suggests that individuals with high PLE may experience being “trapped” in mental time travel, constantly thinking back to past events or forward to imaginary future events, either intentionally or spontaneously. The high scores on the involuntary dimension may reflect a default in intentional cognitive inhibition, as observed for hallucinations (Michie et al., 2005; Waters et al., 2003) and mentioned in Waters et al. (2006) model of memory-based hallucination. Moreover, individuals with high PLE experienced memories and future thoughts involuntarily as often as voluntarily, whereas control participants had significantly fewer involuntary voluntary memories and future thoughts, as evinced by a two-way interaction between type of recall and group. Importantly, a three-way interaction between temporal direction, type of recall and group showed that individuals with high PLE differed from controls, especially with regard to the frequency ratings of involuntary future projections.

Regarding the overall quality of involuntary memory, individuals with high PLE experienced involuntary memories and future thoughts generally as being more emotionally intense than controls, whereas emotional valence was similar in the two groups.

Focusing on the phenomenological characteristics of involuntary memories described by participants, high PLE individuals rated their involuntary memories equally coherent and more vivid, more intrusive and associated with a stronger feeling of reliving, than did controls. Several of these qualitative characteristics of high PLE individuals' involuntary memory are also enhanced in individuals with high levels of PTSD symptoms (Rubin et al., 2008, 2011). This suggests important similarities in the characteristics of involuntary memories of individuals with high PLE and individuals with increased levels of PTSD symptoms. These results are especially important as studies of patients with schizophrenia (situated at the extremity of the psychosis continuum) have

reported the opposite pattern for voluntary (intentionally and strategically retrieved) memories, which patients with schizophrenia generally experience as less vivid, less coherent and with less feeling of reliving, (Allé et al., 2015; Berna et al., 2011, 2016b). If such differences in the subjective characteristics of voluntary and involuntary memories exist in the psychosis continuum, this might lead patients to misinterpret their involuntary autobiographical memories, or, possibly, make it more difficult to distinguish involuntary memories from perceptual phenomena, which could be specific to psychosis.

The involuntary memories of participants with high PLE also tended to worsen their mood, in contrast to controls, whose emotional state mostly improved or was unaffected, according to the retrospective ratings. Importantly, we also found that involuntary memory content differed between groups: individuals with high PLE spontaneously remembered mostly traumatic and life threatening events (32.2% of involuntary memories), whereas controls had more memories related to childhood mundane events, daily life events, failures or humiliation. The role of past trauma is particularly critical for understanding psychosis, as the risk of psychosis is almost threefold greater in individuals with a history of childhood trauma (Varese et al., 2012) and up to 34% of those diagnosed with a psychotic disorder have experienced past trauma (Bonoldi et al., 2013). Moreover, it has been shown that early trauma, such as sexual or physical abuse, often precedes onset of auditory hallucinations (Read et al., 2005), with which it is specifically associated (especially in the case of verbal auditory hallucinations) in both clinical (Hardy et al., 2005; Read and Argyle, 1999; Reiff et al., 2012) and non-clinical populations (Morrison and Petersen, 2003). The present findings showing enhanced involuntary recollection of past trauma in individuals with high PLE are in line with Steel's (2005) traumatic-psychosis model.

Taken together, the present findings showed that involuntary autobiographical memories of individuals with high PLE were more emotionally intense, had greater negative mood impact and were associated with negative content, such as past traumatic experiences, suggesting enhanced emotional responses associated with involuntary autobiographical memory in high PLE individuals. Weaker emotion regulation has been observed in psychosis and might contribute to its development, translating childhood trauma into distressing psychotic experiences in later life (Lincoln et al., 2017). The present results suggest that involuntary memories of individuals with high PLE might also be affected by emotion regulation deficits, maybe accounting for the relationship observed between the emotional intensity of involuntary autobiographical memory and future projections, on the one hand, and hallucination-proneness, on the other (Allé et al., 2018).

The qualitative characteristics and the content of involuntary autobiographical memories of individuals with high PLE formed a specific pattern that has not been previously shown: Individuals with high PLE described their involuntary memories as highly frequent, intrusive, associated with a feeling of reliving, emotionally intense and related to past trauma. Interestingly, these phenomenological characteristics are comparable to those of hallucination. Hallucination is known to be

involuntary and intrusive (Morrison et al., 1995; Nayani and David, 1996), associated with high emotion arousal (Badcock et al., 2011; Mertin and O'Brien, 2013), and related to emotion regulation deficit (Badcock et al., 2011) and threatening content (Steel, 2015). These qualitative similarities between hallucinations and involuntary autobiographical memories can be seen to provide further evidence that hallucination could derive from, or at least be related to, autobiographical memory (Hardy et al., 2005; Steel, 2015; Waters et al., 2006).

Some limitations in the current study need to be acknowledged. First, participants of the high PLE group reported lifetime psychiatric diagnosis (such as depression or anxiety disorders), or current medication, that might have impacted our results. Therefore, we conducted additional analyses (not reported in the present article) in which we removed participants who reported lifetime depressive and/or anxiety disorders. Importantly, these analyses showed exactly the same pattern of results as those presented here, meaning that the present findings cannot be driven by depressive or anxiety symptoms of individuals with high PLE. These additional analyses strengthen our conclusions with regard to the psychosis continuum. Considering previous studies showing no effect of antidepressant treatment on autobiographical memory (Gallassi et al., 2006; McBride et al., 2007), our results most likely were not affected by the current medication reported by eight participants. Second, because we did not collect information about the participants' trauma history, we are unable to rule out that the higher frequency of trauma-related involuntary memories in high PLE group might be driven by group differences in trauma history. However, it should be emphasized that only three participants with high PLE reported a lifetime PTSD diagnosis, which seems to speak against trauma history as a central factor. Still, future research should examine trauma history in individuals with high PLE and how this may affect characteristics of their involuntary memories.

In conclusion, this study showed that involuntary autobiographical memories and future thoughts are quantitatively and qualitatively enhanced in the psychosis continuum, and adds to our understanding of the relationship between involuntary memory and hallucination-proneness (Allé et al., 2018). To more fully understand the implications of these findings, future research should examine qualitative and quantitative characteristics of involuntary autobiographical memory and future projection in patients with clinical schizophrenia, to examine if the present findings extend to the whole psychosis continuum. In addition, memory of context, which has been shown to be impaired in schizophrenia (Rizzo et al., 1996), needs to be specifically assessed in patients' autobiographical memories in order to test the prediction that hallucinations derive from memories that are not recognized by patients as self-generated because of their lack of contextual information (Waters et al., 2006). Finally, patients with schizophrenia mainly display auditory hallucinations (Lim et al., 2016), whereas it has been shown, in the healthy population, that autobiographical memory is mostly associated with visual imagery (Greenberg and Rubin, 2003). The role of auditory versus visual mental imagery in autobiographical memory should be investigated in depth in the psychosis continuum to attain a deeper understanding of the relation between autobiographical memory and the development of hallucination.

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## Conflict of interest

The authors have no conflict to declare.

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