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“Being there” and remembering it: Presence improves memory encoding

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ABSTRACT

Few studies have investigated the link between episodic memory and presence: the feeling of “being there” and reacting to a stimulus as if it were real. We collected data from 244 participants after they had watched the movie *Avengers: Age of Ultron*. They answered questions about factual (details of the movie) and temporal memory (order of the scenes) about the movie, as well as their emotion experience and their sense of presence during the projection. Both higher emotion experience and sense of presence were related to better factual memory, but not to temporal order memory. Crucially, the link between emotion and factual memory was mediated by the sense of presence. We interpreted the role of presence as an external absorption of the attentional focus toward the stimulus, thus enhancing memory encoding. Our findings could shed light on the cognitive processes underlying memory impairments in psychiatric conditions characterized by an altered sense of reality.

“*Virtual Reality is the representation of possible worlds and possible selves, with the aim of making them appear as real as possible—ideally, by creating a subjective sense of “presence” in the user. Interestingly, some of our best theories of the human mind and conscious experience describe it in a very similar way*”

Thomas Metzinger, “2016: What do you consider the most interesting recent scientific news?” *Edge.org*.

1. Introduction

Humans are endowed with the ability to create realistic mental representations of events that are, have been or might be. At the heart of this ability to transcend time and space lies episodic memory (EM), defined as the conscious re-experiencing of personal events combined with the recollection of the phenomenological, spatial and temporal encoding contexts (Tulving, 2002). These multiple components are linked together by a neurocognitive process known as *binding* (Kessels, Hobbel, & Postma, 2007). Ongoing research indicates that the quality of the encoded memory trace is modulated by several aspects of the stimulus as well as by the brain and body states during encoding (Hayes et al., 2010; Otten, Henson, & Rugg, 2002). One of the factors facilitating subsequent recollection is the emotional nature of the stimulus to be encoded. This emotion-related memory enhancement is strong, long-lasting (Yonelinas & Ritchey, 2015) and is based on the close neuro-anatomical connection and interaction between the amygdala and the hippocampus (Greenberg et al., 2005; Richardson, Strange, & Dolan, 2004). For example, both pleasant and unpleasant pictures are

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better recalled than neutral ones and elicit an earlier neural processing, indicating a privileged access of emotional stimuli to cognitive resources (Dolcos & Cabeza, 2002). The same pattern of results has been found for other emotional material such as words (Kensinger & Corkin, 2003) and faces (Sergerie, Lepage, & Armony, 2005). The literature suggests that emotions “capture” attention toward the stimulus (Öhman, Flykt, & Esteves, 2001), allocating cognitive resources for in-depth processing that, in turn, facilitates memory encoding. Indeed, attention plays a pivotal role in memory encoding. Several studies have shown an advantage in subsequent recollection for items encoded in a full compared to a divided attention condition (Anderson et al., 2000; Naveh-Benjamin, Craik, Gavrilescu, & Anderson, 2000). The literature suggests a dissociation between top-down and bottom-up attentional mechanisms in memory formation (Turk-Browne, Golomb, & Chun, 2013). Top-down orienting of attention may facilitate the elaboration of the stimuli in sensory brain structures that, in turn, provide a high-fidelity representation to the hippocampus, leading to a better encoding. On the other hand, bottom-up attention reallocation could exert an opposite effect, hindering memory encoding.

Another phenomenon linked to enhanced memory performances is the so-called enactment effect (Engelkamp, 1998). Sentences describing actions are better remembered if, during the encoding phase, they are performed by the subject, compared to conditions in which they are performed by the experimenter or encoded verbally (Mulligan & Hornstein, 2003). The role of active motor interaction in enhancing episodic memory encoding has been replicated in more realistic settings using virtual reality (Brooks, 1999; Jebara, Orriols, Zaoui, Berthoz, & Piolino, 2014; Plancher, Barra, Orriols, & Piolino, 2012). In these studies, participants who were allowed to actively interact with a virtual environment showed better binding performance in a subsequent recall test than those assigned to passive navigation. More recently, in an elegant study, Bergouignan, Nyberg, and Ehrsson (2014), using an out-of-body illusion induced during an ecologically salient social interaction, showed that experiencing events from the first-person perspective of one’s own body is necessary for accurate EM encoding.

Interestingly, first-person perspective, interactivity, emotion experience and attentional engagement are together the pillars of presence (Coelho, Tichon, Hine, Wallis, & Riva, 2006; Witmer & Singer, 1998). Presence is commonly defined as the feeling of “being there”, i.e. the feeling of being located in, and responding to (whether consciously or not) a mediated environment as if it were real (Barfield, Zeltzer, Sheridan, & Slater, 1995; Sanchez-Vives & Slater, 2005). Originally introduced to describe the feeling that may arise when agents remotely interact with teleoperator devices (telepresence; Minsky, 1980), presence has subsequently been studied mainly in the field of virtual reality (VR). Lately, this concept has received considerable attention from researchers working in different domains such as psychiatry, cognitive neuroscience, and philosophy (Seth, Suzuki, & Critchley, 2012), and its definition has extended to the feeling of being located and fully engaged in a perceived external world around the self (Waterworth, Waterworth, Mantovani, & Riva, 2010). Some authors have even suggested that presence in mediated worlds does not fundamentally differ from presence in the real one (Riva, Waterworth, & Waterworth, 2004). Thus, nowadays, it is considered as a key phenomenon for understanding normal and altered states of consciousness (Loomis, 1992; Sanchez-Vives & Slater, 2005; Seth et al., 2012).

While the increasing popularity of the investigation on presence in different theoretical domains has certainly produced important insights, it has also led to some confusion in the terminology employed in the literature. For the sake of clarity, in the following, we will briefly summarize the major current theoretical frameworks and define the terminology employed throughout the present work. In the VR domain the study of presence is tightly linked to that of immersion that is defined as the extent to which a system can, thanks to its technical properties, deliver a convincing (real-like) and surrounding (isolating from the real world) environment with which an agent can interact (Sanchez-Vives & Slater, 2005). Many features of the system contribute to its immersive capability, such as the field of view, the frame rate, the stereopsis, the presence of coherent multisensory information, the degree of accuracy in matching the simulated sensory data with proprioceptive signals, and the possibility to interact with the virtual environment. All these features are objective properties of the system and are also referred to as media form (Coelho et al., 2006). Hereafter, we will use the term *media immersion* (Slater, 1999) to refer to this component. Beyond technical features of the system, the content of the mediated environment could influence presence. For example, emotional features or narrative consistency of the scenario can increase presence irrespective of media immersion (Coelho et al., 2006; Gorini, Capideville, De Leo, Mantovani, & Riva, 2011). We will call all these features *media content*. Finally, neurocognitive features of the participants, such as attentional engagement toward and willingness to endorse the mediated scenario, could play a role in modulating presence. Several theoretical proposals have suggested that presence in inseparable from attentional factors (e.g., Witmer & Singer, 1998). Selective attention toward the virtual world, and the exclusion of distracting information (i.e., the real environment or self-generated thoughts) seem a central precondition to experience presence (Darken, Bernatovich, Lawson, & Peterson, 1999). These processes will be referred to as *user characteristics*. The term *presence* will only be used here to indicate the subjective response to the mediated environment that likely results from the interaction of all the aforementioned components.

Given the overlap between the factors influencing memory encoding and those triggering presence, it is surprising that no study has directly investigated the link between these two processes. Here, for the first time, we tested the hypothesis that increased presence would facilitate memory encoding. Moreover, we investigated this phenomenon in a highly ecological setting, taking advantage of the renewed interest in 3D movies and the large audiences they reach. Some studies suggest that movies presented in 3D are rated as more credible, more realistic and more immersive than those in 2D (Pölönen, Salmimaa, Aaltonen, Häkkinen, & Takatalo, 2009), resulting in an increased presence (IJsselsteijn, de Ridder, Hamberg, Bouwhuis, & Freeman, 1998; IJsselsteijn et al., 2001). Consequently, we hypothesised that thanks to a greater media immersion, a movie in 3D, compared to 2D, would be associated with increased presence and consequently be associated with better memory performance. Moreover, as presence is also modulated by other factors than media immersion, we expected that, independently of the movie format, the subjectively reported presence would be associated with memory performance. This original methodology allowed us both to exert a rigorous control on the stimulus (the movie was the same for all subjects) and to have a fully ecological in-field setting. The people going to the cinema were self-motivated in doing so, and contrary to most experimental settings, they were unaware that they were taking part in a memory test, making it

Table 1
Summary statistics.

Score	2D	3D	95% CI	*p* value
Participants				
Population	n = 115 (33% ♀)	n = 129 (30% ♀)		
Age	26.67 ± 7.63	26.55 ± 8.44	[−2.15; 1.92]	> 0.05
Delay	7.20 ± 6.31	8.91 ± 5.97	[−3.26; −0.16]	> 0.05
Familiarity with characters	6.25 ± 1.02	6.05 ± 1.17	[−0.07; 0.48]	> 0.05
Variables of interest				
Emotion experience	4.23 ± 1.26	4.30 ± 1.20	[−0.38; 0.64]	> 0.05
Presence	4.19 ± 1.48	4.32 ± 1.28	[−0.46; 0.21]	> 0.05
Factual memory	0.57 ± 0.15	0.54 ± 0.15	[−0.01; 0.06]	> 0.05
Temporal order memory	0.49 ± 0.76	0.44 ± 0.84	[−0.02; 0.12]	> 0.05

In the upper part of the table are reported: the age, the number of participants in each set-up (2D-3D), the delay between seeing the movie and responding to the questionnaire expressed in days, the familiarity with this particular film-genre, the level of familiarity with the movie characters. The latter two variables were measured on a 7-point scale. The bottom part reports the summary statistics for the variables of interest: emotion experience (range 1–7), presence (range 1–7), factual memory (range 0–1), and temporal order memory (range 0–1). The p values are Bonferroni corrected.

possible to study incidental encoding processes that are closer to those at stake in the formation of episodic memories.

2. Material and methods

2.1. Participants

Two hundred and sixty-eight participants completed the on-line questionnaire. Forms received more than 30 days after the participants had watched the movie were excluded, however, leading to a final sample of 244 participants, among whom 115 (47%) viewed the movie in 2D and 129 (53%) in 3D (respectively; mean age: 26.56 ± 7.63, mean age: 26.67 ± 8.44). The two groups did not differ in gender ratio (2D 33% Female, 3D 30% Female, $\chi^2 = 0.21$, $p > 0.05$). There was no difference between the two groups in age, delay between seeing the movie and the completion of the questionnaire, and familiarity with the movie characters (see Table 1). Participants were fully informed of the academic nature of the study and the voluntary nature of their participation. The local ethics committee approved the study.

2.2. The movie

The perquisites for the movie were to include live-action actors and scenes, to be available in both 2D and 3D format, and to be widely appealing and potentially attended by a large and diverse audience. For these reasons, the movie *Avengers: Age of Ultron* (Whedon, 2015, http://marvel.com/avengers) was chosen. The movie set is a realistic world with elements of fantasy (super-heroes) and mixed features of many sub-genres of narrative interest, such as action, comedy, romance, and drama (see Supplementary Table 1 for the synopsis of the movie).

2.3. Procedure

We distributed handouts to people leaving theatres after watching the movie, with a link to an on-line questionnaire, and used advertisement on social networks. Questions measuring demographic information (age, sex, familiarity with the movie characters), memory, emotional experience, and presence were presented (described below). The form was put on-line using Google Forms©, and statistical analyses were performed using R (R Development Core Team, 2008). For each dimension, a Cronbach's alpha superior to 0.70 was considered as an acceptable internal reliability index (Darren & Mallery, 1999), leading to the averaging of the scores.

2.3.1. Factual memory

Twenty-seven memory questions were constructed by the first two authors immediately after the projection of the movie (notes to construct the questionnaire were taken during the projection of the movie). These questions had four possible answers, plus one “I don't know” (e.g., what is the colour of the cocktail that Bruce Banner and Natasha drink at Stark’s party? Red, Blue, Green, Transparent, I don’t know). Scores were collected on a binary true/false mode. However, from this initial set of questions, two were removed, one for being non-sensitive (100% of correct answers), and the other one for having an arguable answer. The memory score was computed as the ratio of correct answers on the number of questions. The list of questions is presented in the Supplementary Table 2.

2.3.2. Temporal order memory

Temporal order memory was tested by asking participants to rearrange in the correct sequence verbal descriptions of 10 important scenes from the movie (see Supplementary Table 3). The order of the scenes was randomised across participants. One point was assigned to each scene that was correctly placed between the previous and the following scene. For example, the answer was scored as correct if the scene n°4 was placed between scenes n°3 and n°5. The total score was computed as the ratio of correct answers on the maximum score 10.

2.3.3. Presence

Presence was measured by 14 questions (on a 7-point Likert scale, *e.g.*, *"I was reacting to everything I was seeing as it was real"*) specifically constructed for the current study, but heavily based on the leading questionnaire on Presence: the *ITC-Sense of Presence Inventory* (ITC-SOPI; Lessiter, Freeman, Keogh, Davidoff, & Keogh, 2001). This questionnaire showed excellent internal reliability ($\alpha = 0.93$). Items are reported in Supplementary Table 4.

2.3.4. Emotion experience

Three questions (on a 7-point Likert scale) were administered as a measure of the emotion experience during the film: the prevalent valence of emotions (Negative - Positive), the overall intensity of emotions (Weak-Strong), and the frequency at which these emotions were experienced during the film (Never-Very Frequently). However, due to a strong correlation among the three scores (intensity – frequency: $r = 0.76$, $p < 0.001$; valence – intensity: $r = 0.64$, $p < 0.001$; valence – frequency: $r = 0.60$, $p < 0.001$, $\alpha = 0.86$), they were averaged into a single measure.

3. Results

3.1. The immersive 3D setup

There was no significant difference between participants who saw the film in 3D and those who saw it in 2D in any of the variables of interest: factual memory ($t_{(242)} = 1.96$, $p > 0.1$, 95% CI $[-0.001, 0.45]$), temporal order memory ($t_{(242)} = 1.34$, $p > 0.1$, 95% CI $[-0.23, 1.20]$), presence ($t_{(242)} = -0.53$, $p > 0.1$, 95% CI $[-0.86, 0.49]$), and emotional experience ($t_{(242)} = -0.96$, $p > 0.1$, 95% CI $[-0.51, 0.17]$), see Table 1.

3.2. Correlation analysis

We ran correlations between the variables of interest on the whole sample. Emotion experience, presence, and factual memory were strongly correlated (see Table 2). Nevertheless, partial correlations showed that the link between emotion experience and factual memory was mediated by subjective presence ($r^* = 0.12$, $p > 0.05$). On the contrary, the correlation between presence and factual memory remained significant even when controlling for the emotion experience ($r^* = 0.15$, $p < 0.05$; see Fig. 1). The temporal order memory score correlated with factual memory ($r = 0.44$, $p < 0.001$), but we did not find any significant correlations between this measure and the emotion experience ($r = -0.004$, $p > 0.05$) or subjective presence ($r = 0.03$, $p > 0.05$).

3.3. Mediation analysis

To further support the results of the previous analysis, we ran a mediation analysis employing structural equation modelling (lavaan R package; Rosseel, 2012; Shevlin et al., 2015). A mediation model was fitted, with emotion experience as predictor, factual memory as outcome, and presence as mediator. As recommended, bootstrapping (nsim = 1000) was used to estimate standard errors (SE). The R code for this analysis is provided in the supplementary materials. Within this model, the "direct" effect of emotion experience on factual memory did not reach significance ($\beta = 0.018$, SE = 0.010, $p > 0.05$). Concerning the mediation path, presence was significantly predicted by emotion experience ($\beta = 1.34$, SE = 0.11, $p < 0.001$), and factual memory by presence ($\beta = 0.010$, SE = 0.005, $p < 0.05$). Overall, the "indirect" effect of emotion experience on factual memory (the one mediated by presence) was significant ($\beta = 0.014$, SE = 0.006, $p < 0.05$), as well as the total effect (both the direct and indirect effects; $\beta = 0.032$, SE = 0.008, $p < 0.001$).

In order to address the issue of the alternative effect direction, we also fitted the model with presence as predictor, factual memory as outcome, and emotion experience as mediator. The same parameters were used. Within this model, the "direct" effect of presence on factual memory was significant ($\beta = 0.010$, SE = 0.004, $p < 0.05$). Concerning the mediation path, emotion

Table 2
Correlations between the variables of interest.

	Presence	Factual memory	Temporal memory
Emotion experience	0.62^{***}	0.26^{***}	0.006
Presence		0.27^{***}	0.06
Factual memory			0.45^{***}

$^{*}p < 0.05$.
$^{**}p < 0.01$.
$^{***}p < 0.001$

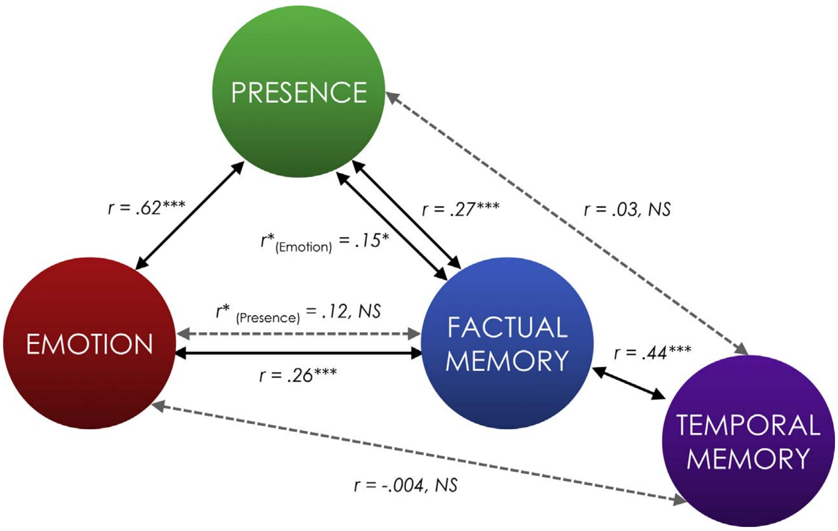

Fig. 1. Relationship between presence, emotion and memory. The correlations between Presence, Emotion, Factual and Temporal Memory on the whole sample. The r*'s are the estimated partial correlation coefficients when adjusting for the factor in brackets. (***$p < 0.001$, *$p < 0.05$, NS: $p > 0.05$).

experience was significantly predicted by presence ($\beta = 0.28$, $SE = 0.023$, $p < 0.001$), but factual memory was not predicted by emotion experience ($\beta = 0.018$, $SE = 0.010$, $p > 0.05$). Overall, the "indirect" effect of presence on factual memory (the one mediated by emotion experience) was not significant ($\beta = 0.005$, $SE = 0.003$, $p > 0.05$), as opposed to the total effect (both the direct and indirect effects; $\beta = 0.015$, $SE = 0.003$, $p < 0.001$).

4. Discussion

In this study, we gathered data on memory for a "real-life" event (viewing a movie) that was inherently self-relevant, since participants were internally motivated and had no knowledge of the experimental purpose during the event. We hypothesised that the higher media immersion provided by a 3D set-up would increase presence that, in turn, would facilitate memory encoding. Moreover, we expected that presence, independently of the presentation format, would modulate subsequent memory performance. The first hypothesis was not confirmed. There was no difference between the 3D and the 2D conditions on presence or on the two memory scores (factual and temporal order memory). We found however that, independently of the movie format (2D-3D), the subjective sense of presence was correlated with the emotion experience and the factual memory score. Moreover, presence mediated the correlation between emotion experience and the factual memory scores.

4.1. Presence is not modulated by the 3D set-up, but by the emotion experience

Contrary to some previous studies, we did not observe a modulation of presence by the 3D setup (IJsselsteijn et al., 1998, 2001; Rooney, Benson, & Hennessy, 2012; Rooney & Hennessy, 2013). Despite the fact that a previous study did not report it either (Baños et al., 2008), several hypotheses can be put forward to explain this result. Firstly, some of the aforementioned studies (IJsselsteijn et al., 1998, 2001) used a specific laboratory apparatus, where the subject was alone and the stereoscopic depth adjusted to her position, rather than generic theater technology. Rooney et al. (2012) used a mini 3D cinema (2.5 m^2) that can be considered, along with the study by Baños et al. (2008), comparable to the setting of the present work. In these two studies, presence was measured by a specific subscale of the ITC-Sense of Presence Inventory (ITC-SOPI) (Lessiter et al., 2001): the ecological validity subscale. This measure indicates "the level to which a viewer perceives the mediated environment as lifelike and real" (Rooney et al., 2012, pp. 412–413). Nevertheless, recently other factors influencing presence such as emotional engagement, self-relevance, and narrative consistency have been emphasized, beyond the perceptual aspects of the experience. For example, Hall (2003) identified six dimensions that contribute to realism, and *perceptual persuasiveness* is only one of them. It is therefore possible that the 3D condition did not yield alone a sufficient difference to operate a significant modulation on the sense of presence.

In accordance with previous studies, we found that the sense of presence was strongly correlated with the emotion experience. The role of emotions in triggering a sense of presence has been demonstrated by many studies and is often considered as the most important predictor of presence (Baños et al., 2004, 2008; Riva et al., 2007; Villani, Repetto, Cipresso, & Riva, 2012; Västfjäll, 2003). Tan, Lewis, Avis, and Withers (2008) proposed that presence, attention and emotion sustain each other in a symbiotic fashion. Seth et al. (2012) go a step further, suggesting that presence is mainly related to interoceptive inputs, and thus intrinsically connected to emotions, rather than exteroceptive ones. They argue that emotional engagement is sufficient to generate a feeling of "being there", as suggested by the high sense of presence that one can experience when reading a good book (a medium with low media immersion). In this wider view of presence as a multi-determined construct, the absence of noticeable modulation of the sense of presence by the 3D setting is not incoherent.

Another issue concerns the nature of the movie itself (media content), involving non-realistic fictive elements (such as superheroes, robots, etc.). However, since both groups saw the same fictional movie, it is unlikely that the impact of the media content can explain our findings. Nevertheless, the effect of fiction on cognition, and more specifically on emotion, has been a hot topic in philosophy, and has just started to attract the interest of neuroscientists. Known as the "paradox of fiction", it summarily posits that one cannot feel genuine emotions toward characters and events while knowing and believing that they are not real (Radford & Weston, 1975). Experimental studies suggest that the difference in emotions toward reality and fiction lies in the intensity of their expression, rather than in their essence. Several studies indicate that fiction induces a form of emotion down regulation (Mocaiber et al., 2010; Sperduti et al., 2016, 2017). Probably, fiction constitutes an appraising framework mediating the link between emotion and presence. Overall, the findings are coherent with a synergetic and almost circular link between emotion, presence and fictional appraisal. Indeed, while emotion can prompt presence, appraising an event as fictional seems to down regulate emotion, and may produce a diminished presence. On the other hand, fictional events recognized as such can still be experienced as intensely emotional and produce a high presence according to our current results and many VR experiments (that are set in a fictive world).

4.2. Temporal order memory is not modulated by presence

Contrarily to factual memory, memory for temporal order correlated neither with the emotion experience nor with the degree of subjective presence. The knowledge of the mechanisms subserving the encoding of contextual information (i.e., temporal order) is relatively sparse. There is compelling evidence suggesting that they could partially be dissociated from those engaged in factual memory encoding, since item and contextual memory encoding have been shown to recruit different medial temporal lobe (MTL) structures (Davachi, Mitchell, & Wagner, 2003). Moreover, temporal order memory, but not memory for items, has been reported to be impaired in patients with frontal lobe lesions (Mangels, 1997; Shimamura, Janowsky, & Squire, 1990), and a similar dissociation, related to the diminished recruitment of frontal structures, has been reported in normal aging (Cabeza, Anderson, Houle, Mangels, & Nyberg, 2000). The role of emotion in modulating the encoding of contextual temporal information is not well understood, and results in this domain are quite contradictory (for a recent review, see Chiu, Dolcos, Gonsalves, & Cohen, 2013). For example, Schmidt, Patnaik, and Kensinger (2011) reported that items characterized by high arousal, independently of their valence (positive or negative), were better remembered along with their temporal context, compared with low arousal items. On the contrary, Huntjens, Wessel, Postma, van Wees-Cieraad, and de Jong (2015) reported that participants performed less well in reordering highly arousing pictures in the correct temporal sequence, and that this effect was more pronounced for negative material. Using a more ecological approach, Zlomuzica, Preusser, Totzeck, Dere, and Margraf (2015) showed that negative emotion arousal induced by short movie clips, prior to the navigation of a virtual reality scenario, was associated with poorer memory for the spatial context, but not for the temporal order of events encountered in the scenario. The absence of modulation of temporal order memory by the emotion in the present work is in agreement with the latter study. The discrepancy between the aforementioned results might be due to methodological differences. Indeed, it is important to note that in the first two studies, the authors directly manipulated the emotional features (valence and arousal) of the item to be encoded, and employed intentional encoding, while Zlomuzica et al. (2015) induced an emotional state before incidental encoding of neutral material. Further work should elucidate in which circumstances emotion modulates the encoding of contextual information, in particular temporal memory.

4.3. Emotion and presence enhance factual memory encoding

We found that people that had a stronger emotion experience showed better factual memory scores. The encoding advantage of emotional material has been repeatedly reported (e.g., Dolcos & Cabeza, 2002). However, it is important to note that most of the previous studies manipulated the emotional content of the to-be-encoded material and not the participants' emotional state. Thus, it is not clear how the magnitude of emotional reaction to the same material can influence memory encoding. Interestingly, two studies have shown that the interindividual variability in the activity of the amygdala while watching arousing films correlated with subsequent recall (Cahill et al., 1996; Canli, Zhao, Brewer, Gabrieli, & Cahill, 2000). These findings, together with our data, suggest that the subjective emotional state in reaction to the same objective stimulus could enhance memory encoding through a mechanism subserved by the activation of the amygdala and its modulation of perceptual and higher-level cortical areas responsible for attentional control (Hamann, 2001; Murty, Ritchey, Adcock, & LaBar, 2011).

Beside the correlation between the emotion experience and memory performance, we also found that greater presence coincided with higher factual memory scores. Due to the strong correlation between presence and emotion, one plausible explanation is that this result simply reflects the effect of emotion on memory. Nevertheless, we do not only report that the link between presence and memory remained significant after adjusting for emotion but, centrally, we found that presence mediates the link between emotion and memory.

What mechanism could explain the additional advantage of presence, beyond emotion, on memory encoding? One possible explanation is that enhanced presence is characterized by an increased attentional engagement toward the event (in this case the film). As mentioned in the introduction, attentional engagement seems to be a central mechanism grounding presence. Indirect evidence for this hypothesis comes from a study showing that trait-absorption is associated with superior autobiographical memory abilities (Patihis, 2016). This concept is linked to that of presence since it is defined as the "disposition for having episodes of 'total' attention that fully engage perceptive and imaginative resources, resulting in a heightened sense of reality towards the object of attention" (Tellegen & Atkinson, 1974, p. 268). The author explained these findings by proposing that absorption may enhance attention during the encoding phase. Interestingly, higher absorption has also been linked to an increased false memory rate employing a classical Deese-Roediger and McDermott paradigm (DRM; Meyersburg, Bogdan, Gallo, & McNally, 2009), and to enhanced susceptibility to misinformation in false memory formation in participants with highly superior autobiographical memory (Patihis et al., 2013). Taken together, and in line with the results of Merckelbach (2004), these findings suggest that increased presence could have either a beneficial or a detrimental effect on memory performance depending on whether misleading information is present or not.

The impact of attentional processes on memory is well documented, and seems to act mostly during the encoding phase. Indeed, several studies have reported that memory performance is hindered by divided attention during encoding, but not during retrieval (Baddeley, Lewis, Eldridge, & Thomson, 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996; Naveh-Benjamin, Craik, Guez, & Dori, 1998; Naveh-Benjamin et al., 2000). This attentional benefit on encoding processes is sustained by the enhanced recruitment of prefrontal regions that exert a top-down modulation on sensory and medial temporal lobe structures (Kensinger, Clarke, & Corkin, 2003; Naveh-Benjamin et al., 2000; Turk-Browne et al., 2013; Uncapher & Rugg, 2005).

We propose that presence is linked to selective attention toward the stimulus, and consequently to reduced processing of irrelevant external (e.g., noises produced by other people in the theater) and internal (e.g., self-generated thoughts) distractors. We suggest that this mechanism is subserved by the recruitment of top-down attentional structures, such as the prefrontal cortex. This is consistent with neuroimaging findings showing that the ventrolateral prefrontal cortex is activated during episodes of adhesion (the belief that the fiction is real) toward a theater play (Metz-Lutz, Bressan, Heider, & Otzenberger, 2010). This region has repeatedly been associated with successful memory encoding (for a recent meta-analysis see Kim, 2011), and its activity is reduced during encoding under divided attention (Uncapher & Rugg, 2005).

4.4. Presence as a conscious state and its alteration: impact on memory

We showed, in line with previous findings, that subjective presence was linked to the emotional reaction toward the event (a film). Nevertheless, it seems that presence cannot be explained by the emotion experience alone, since its effect on subsequent memory performance remained significant when adjusting for the emotion experience at encoding. We suggest that, when facing an event, an emotional reaction could constitute a pre-attentional mechanism that enhances perceptual processing and engages attentional resources in a bottom-up fashion. This then acts as a trigger for the sense of presence. Presence is subsequently sustained by top-down attentional processes, which further accrue selective attention toward the on-going event, and eventually diminish resource allocation toward possible distractors. Indeed, emotions and attention are two interacting systems. On the one hand, emotional stimuli can capture attention. On the other hand, attention is necessary to sustain emotional reaction.

We suggest that these mechanisms are subserved by two independent, but interacting, networks sustaining their activity reciprocally. The first network is composed of areas linked to emotional processing including the amygdala, and the second encompasses fronto-parietal structures responsible for attentional control. Both networks have been shown to modulate activity in medial temporal structures (the hippocampus and parahippocampus) during memory encoding. Thus, increased presence may constitute an optimal state of consciousness to favour memory encoding.

Some authors have suggested that presence in mediated worlds does not fundamentally differ from presence in the real one (Riva et al., 2004). Interestingly, several psychiatric disorders, such as depersonalization/derealization disorders (DDD), are characterized by both an altered sense of reality (diminished presence in our framework) and memory impairments (American Psychiatric Association, 2013). Our study suggests that these two dysfunctional processes could be closely linked, in that decreased presence could lead to impaired memory encoding. Even if speculative, this hypothesis could be of epistemological relevance in guiding and reframing neuropsychiatric research on depersonalization and derealization as altered states of consciousness.

5. Limitations, perspectives and conclusion

The major limitation of our study that was due to the very nature of the methodology employed, is that we only collected self-reported measures of emotion and presence. Future studies, using a similar methodology, but in more controlled laboratory settings, could take advantage of the use of real-time physiological (*e.g.*, Skin Conductance Response and EEG) and behavioural (e.g., eye tracking) measures as objective markers of emotional and attentional processes.

Nevertheless, using an ecologically valid procedure we were able to show that increased presence was associated with memory accuracy. We have proposed that this benefit results from the interaction of emotional and attentional processes. We further suggest that presence could be conceptualised as a state of consciousness and that its alteration, observed in several psychiatric conditions, could be at the root of the memory dysfunctions reported in these disorders. This study could represent a step toward a neuroscientific approach to the study of presence as an integrative field of research at the crossroads between emotion, attention, memory, and consciousness. Future studies should elucidate the neural underpinning of presence and its dysfunction in psychiatric diseases.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.concog.2017.06.015.

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