Consciousness and Cognition 124 (2024) 103731

Contents lists available at ScienceDirect

Consciousness and Cognition

journal homepage: www.elsevier.com/locate/yccog

Psychological dissociation and temporal integration/segregation across the senses: An experimental study

Marco Cavicchioli [a,e,1,*], Alessia Santoni [b,1], Francesco Chiappetta [b,1], Michele Deodato [c], Giuseppe Di Dona [b], Andrea Scalabrini [d], Federica Galli [a], Luca Ronconi [b]

[a] Department of Dynamic and Clinical Psychology, and Health Studies, Faculty of Medicine and Psychology, SAPIENZA University of Rome, Italy
[b] School of Psychology, Vita-Salute San Raffaele University, Milan, Italy
[c] Psychology Program, Division of Science, New York University Abu Dhabi, United Arab Emirates
[d] Department of Human and Social Science, University of Bergamo, Mental Health, Bergamo, Italy
[e] Faculty of Psychology, Sigmund Freud University, Ripa di Porta Ticinese 77, Milan, Italy

ARTICLE INFO

Keywords:
Dissociation
Temporal integration
Hyper-segregation
Hyper-integration
Affective functioning

ABSTRACT

There are no studies that have experimentally tested how temporal integration/segregation of sensory inputs might be linked to the emergence of dissociative experiences and alterations of emotional functioning. Thirty-six participants completed 3 sensory integration tasks. Psychometric thresholds were estimated as indexes of temporal integration/segregation processes. We collected self-report measures of pre-task trait levels of dissociation, as well as pre- post-task changes in both dissociation and emotionality. An independent sample of 21 subjects completed a control experiment administering the Attention Network Test. Results showed: (i) a significant increase of dissociative experiences after the completion of sensory integration tasks, but not after the ANT task; (ii) that subjective thresholds predicted the emergence of dissociative states; (iii) temporal integration efforts affected positive emotionality, which was explained by the extent of task-dependent dissociative states. The present findings reveal that dissociation could be understood in terms of an imbalance between "hyper-segregation" and "hyper-integration" processes.

1. Introduction

1.1. The complexity of dissociation

Dissociation is a multifaceted construct that has been investigated from different perspectives, each referring to specific aspects of mental functioning.

From a psychopathological point of view, the ICD-11 (World Health Organization, 2018) describes dissociation as the "*involuntary disruption or discontinuity in the normal integration of one or more of the following: identity, sensations, perceptions, affects, thoughts,*

* Corresponding author at: Department of Dynamic and Clinical Psychology, and Health Studies, Faculty of Medicine and Psychology, SAPIENZA University of Rome, Italy.

E-mail address: marco.cavicchioli@uniroma1.it (M. Cavicchioli).

[1] These authors have contributed equally to the work.

https://doi.org/10.1016/j.concog.2024.103731
Received 30 May 2024; Received in revised form 19 July 2024; Accepted 23 July 2024
Available online 2 August 2024
1053-8100/© 2024 The Author(s). Published by Elsevier Inc. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/).

memories, control over bodily movements, or behavior" (World Health Organization, 2018). Similarly, the DSM-5 (American Psychiatric Association, 2013) emphasizes the loss of high-order integrative and regulative capacities: "*disruption of and/or discontinuity in the normal integration of consciousness, memory, identity, emotion, perception, body representation, motor control, and behavior*".

Looking at dissociation as a constellation of symptoms, it involves two main types of manifestations (van Dijke et al., 2010): positive symptoms include intrusive experiences (e.g., reexperiencing traumatic memories), whereas negative symptoms refer to "*apparent losses — apparent because experiences that tend not to be available to one dissociative part of the personality may actually be available to another part*" (van Dijke et al., 2010, p. 426). A further categorization of dissociative symptoms refers to psychoform (Maldonado and Spiegel, 1998) and somatoform (e.g., pain; anesthesia) phenomena (Nijenhuis, 2001; Nijenhuis et al., 1996), with respect to the domain of expression of such psychopathological manifestations.

Furthermore, one of the most influential approaches to dissociation conceptualizes this construct as a psychological dimension (Bernstein & Putnam, 1986; Carlson & Putnam, 1993). Specifically, dissociative phenomena range from milder forms with no significant interference on adaptation (e.g., absorption, daydreaming; Dalenberg and Paulson, 2009; Eisen and Carlson, 1998), which mainly capture alterations in the field and level of consciousness (Van der Hart et al., 2004), to pathological pervasive forms such as in trauma-related and dissociative disorders (Coons, 1996; Van der Hart et al., 2004). Among these latter conditions, dissociation might represent a structural feature of personality (Nijenhuis and Den Boer, 2009; Van der Hart, Nijenhuis, and Steele, 2006) characterized by a loss of integration between parts usually mediated by daily-life action systems (i.e., activities of daily life) and defensive action systems (i.e., a range of subsystems dedicated to the survival of the individual in the face of threat) (Van der Hart et al., 2004).

Some scholars have also proposed to view dissociation in the light of two hypothesized underlying processes, namely compartmentalisation and detachment (Allen, 2001; Holmes et al., 2005), that might explain different dissociative phenomena. Compartmentalization is characterized by a "*deficit in the ability to deliberately control processes or actions that would normally be amenable to such control*" (Holmes et al., 2005; p. 7), which includes an inability to bring normally accessible information into the field of consciousness. Compartmentalized processes continue to operate outside the subjective awareness and intentional control due to deficits with integrative mechanisms of consciousness, and they influence ongoing emotion, cognition and action (Brown, 2006) through dissociative symptoms such as dissociative amnesia, conversion symptoms, somatoform dissociation symptoms (i.e., re-experiencing traumatic pain in the body) (Nijenhuis and Van der Hart, 1999; Van der Kolk, 2014). On the other hand, detachment is defined by the subjective experience of an altered state of consciousness characterized by "*a sense of separation from certain aspects of everyday experience* (Holmes et al., 2005; p. 5)" from the body, emotional experience, sense of self or the external world. Detachment mechanisms might be linked to a wide range of dissociative symptoms including absorption, derealization, depersonalization, together with the absence or alteration of emotional experience (e.g., numbing).

Despite the differences existing among these perspectives, there is a consensus in hypothesizing that dissociation and related phenomena could be understood in the light of alterations of basic integrative processes, which might affect regulatory capacities of human brain and mind (Scalabrini et al., 2017, Scalabrini et al., 2020a; Farina et al., 2019; Schimmenti and Sar, 2019). Furthermore, Farina and Imperatori (2023) have recently suggested a tripartite model that postulates distinct, albeit synergic, pathogenic processes linked to overlapping dissociative manifestations with specific qualities. Precisely, the authors sustain that traumatic experiences lead to a *disintegration* or a loss of integrative functions of the human brain and mind (e.g., the inability to regulate emotional and behavioral responses, a fragmentation of the sense of self, failure of metacognitive monitoring). This disintegration is viewed as a precondition of dissociative phenomena or it could represent a basis for a proneness to dissociative reactions. *Detachment responses* capture alterations of self-consciousness including a sense of separateness from self (i.e., depersonalization) and external world (i.e., derealization). These processes have been considered biological defense mechanisms that dampen the potentially detrimental outcomes of intense affective reactions in face of threatening situations. *Traumatic disintegration* and *detachment responses* in presence of a failure of the caregiver's role in developing a cohesive sense of the self are preconditions of pathological *over-segregation* of mental contents, self-states, and mental functions (*dissociation* or compartmentalization/structural dissociation), which induces a functional reorganization of parallel-distinct structures (e.g., multiple self-states or identity). These over-segregate structures and functions might coexist and/or operate simultaneously.

According to these conceptual perspectives (Scalabrini et al., 2017, Scalabrini et al., 2020a, Farina and Imperatori, 2023; Schimmenti and Sar, 2019), alterations of integration and segregation processes of mental contents, functions and self-states might be considered as core mechanisms at the base of the constellation of dissociative phenomena.

1.2. Integration/segregation processes and neuroscience of dissociation

Neuroscientific theories of brain-mind functioning and consciousness (for reviews see: Deco et al., 2015; Seth & Bayne, 2022) focusing on the key role of integration and segregation processes seem to provide an empirical framework for clinical considerations that view dissociation as a disorder of these basic mechanisms of the brain (Farina and Imperatori, 2023; Scalabrini et al., 2020a).

Particularly, Deco and colleagues (2015) have suggested that integration and segregation processes could be conceptualized considering at least 3 aspects of brain functional organization: i) topographical; ii) functional; iii) spatiotemporal. Looking at a topographical level, integration is promoted by brain networks that show widespread connections among them; whereas segregation is sustained by high densely within-connected networks that are relatively separated to each other. Considering the functional level, integration captures how effectively the brain finds a "common currency" (Northoff et al., 2020) within the flux of information from arbitrary external inputs, which are processed across distributed brain networks. On the other hand, segregation reflects the capacity of the brain to convey the amount of information provided by external inputs during a systematic stimulation. On a spatiotemporal level, integration captures the effectiveness of the brain to bind information across the whole brain over time. On the contrary, segregation measures the ability of the brain to encode information over time coming from varying and distinct inputs. A balance between spatio-temporal integration and segregation processes is thus necessary to facilitate the emergence of coherent and unitary percepts, while at the same time it provides a specific spatio-temporal resolution that allows our brain to process changes in the environment rapidly and efficiently (Wolff et al., 2022; Dixon & Di Lollo, 1994). Taken together, these two synergetic processes are considered to be fundamental for the emergence of subjective experience. Indeed, in everyday life, our perceptual systems constantly process a stream of multisensory information. Spatio-temporal integration and segregation mechanisms enable us to discern whether two stimuli (within or across modalities) originate from the same source and should be thus combined into a single, unified percept. On a higher level, temporal segregation/integration processes contribute to perform complex behaviors that require fine spatio-temporal tracking of multisensory information, ranging from speech processing (Pöppel and Assaneo, 2020), to more complex phenomena such as engaging in social interactions (Kawakami et al., 2018) or maintaining a coherent narrative of the self (Pöppel, 2010). When impaired, temporal segregation/integration processes might account for high-level deficits in the sense of temporal continuity and fragmentation of events (Parsons et al., 2013).

Neuroscientific evidence has also provided empirical support for this conceptual framework proposing a key role of integration/disintegration and over-segregation mechanisms for different dissociative phenomena (Farina and Imperatori, 2023; Scalabrini et al., 2020a). For instance, resting-state functional connectivity analysis showed that individuals with high trait levels of dissociation were characterized by a decreased local connectivity in right anterior insula, in left postcentral gyrus and in right inferior frontal gyrus (Scalabrini et al., 2020a). This evidence was interpreted as a proxy of compartmentalization (i.e., loss of mental contents), which might be sustained by an over-segregation (Farina and Imperatori, 2023) of the unity of specific stimuli at a psychological level (i.e., objectual unity; Bayne and Chalmers, 2003). Scalabrini and colleagues (2020a) also found a reduced resting-state functional connectivity between the insula, which plays a key role in interoception (Craig, 2002), and other cognitive, emotional and sensorial networks (e.g., salience, dorsal attention, visual, auditory, somato-sensory) among individuals with higher levels of dissociation. This evidence suggested a disruption of body-mind integration processes (i.e., disintegration, Farina and Imperatori, 2023) as an additional mechanism associated with several dissociative phenomena. Further empirical evidence was showed by Massullo and colleagues (2022), who demonstrated that individuals with an unresolved attachment style associated to high levels of dissociative traits (Liotti, 2004, 2009) were characterized by a decreased resting-state EEG global efficiency (indexing spatiotemporal integration of cortical activity) after the recall of attachment traumatic memories, but not local efficiency (indexing functional segregation). This result suggested that traumatic disintegration processes, but not over-segregation, might sustain dissociative attachment-related mental states.

Therefore, neuroscience data have provisionally suggested how resting-state activity linked to integration and segregation of mind-brain functions might be involved in different dissociative phenomena. Nevertheless, there is a lack of empirical findings concerning how task-dependent integration and segregation processes might play a role in the emergence of dissociative reactions.

In addition to resting-state functional connectivity evidence, temporal integration and segregation processes have been widely explored administrating specific experimental paradigms, including sensory integration tasks, which are considered the gold standard to quantitatively measure these basic mechanisms (Stevenson et al., 2014; Zhou et al., 2018, 2020). Several previous studies investigated temporal integration/segregation processes in clinical or neurodevelopmental conditions, indicating that sensory integration tasks might represent a valid tool to investigate altered perceptual experiences among individuals with high levels of schizotypy traits, schizophrenia (Deodato et al., 2024; Marsicano et al., 2022), autistic spectrum disorder (Ronconi et al., 2023; Zhou et al., 2021) and developmental dyslexia (Ronconi et al., 2020; Santoni et al., 2024).

While these processes have been extensively investigated in the literature, there are no studies that have tested how specific sensory integration tasks might induce dissociative experiences or, they could be associated with trait measures of dissociation. Furthermore, no studies have explored how temporal integration/segregation processes of external stimuli with and without perceptual characteristics promoting a causal inference might be differentially associated to dissociative phenomena. This distinction seems to be crucial to effectively clarify how integration and segregation processes might be involved in dissociative experiences, especially taking into account empirical data that have demonstrated how dynamic multi-sensory stimuli suggesting a causal inference significantly affect temporal integration/segregation processes compared to stationary ones (Deodato & Melcher, 2022; Kohlrausch et al., 2013; Van Eijk et al., 2008). Specifically, it has been shown that stationary multi-sensory stimuli were characterized by shorter thresholds (i.e., the amount of synchrony between the two stimuli needed to elicit a perceived simultaneity) than dynamic ones (Van Eijk et al., 2008). This evidence indicates that the former are temporally segregated more effectively than the latter, for which it is recognized a more pronounced tendency to temporally integrate (i.e., larger thresholds) distinct cross-modality stimuli due to causal inference induced by their perceptual properties (e.g., collision) (Wang et al., 2022, 2023).

This empirical approach might corroborate the hypothesis that dissociation is strictly connected to mind-brain integration/segregation processes. Furthermore, this might extend the knowledge regarding how integration and segregation processes and related alterations (Wolff et al., 2022) could interplay to each other in sustaining dissociative experiences (Farina and Imperatori, 2023).

1.3. Dissociation and emotional functioning

There is consistent evidence that has shown how dissociative processes and symptoms significantly affect human emotional functioning. For instance, emotional-eliciting events might be dissociated from memory, facilitating the onset of automatic and intense affective reactions that are manifested in a chaotic and incongruous form, such as unmanageable fears and anxiety (Carlson et al., 2009), as well as due to alterations of integration processes (Liotti, 2009; Schore, 2009; Meares, 2012; Scalabrini et al., 2020b). Dissociative symptoms and mechanisms might also interfere with a coherent encoding of salient events (Conway and Pleydell-Pearce, 2000), leading to an unintegrated experience where different aspects of the event such as its sensory, affective and cognitive features are separately encoded and disintegrated automatically (Van der Kolk and McFarlane, 1996; Bremner et al., 1998; Foa and Riggs 1995). These maladaptive encoding processes might lead to the fragmentation of those mental activities involved in adaptive emotion regulation, such as attention and behavioral strategies (Zelazo & Cunningham, 2007).

According to these findings and considerations, several empirical studies investigated the associations between dissociation and adaptive/maladaptive emotion regulation processes involved in influencing positive and negative emotions consciously or automatically, in terms of intensity, duration, and/or quality (Naragon-Gainey et al., 2017). An extensive *meta*-analytic review on this topic (Cavicchioli et al., 2021) demonstrated significant associations between dissociation and dysfunctional domains of emotion regulation (i.e., disengagement and aversive cognitive perseveration) (Naragon-Gainey et al., 2017), suggesting to view dissociation as a constellation of automatic mechanisms with two main maladaptive functions within the context of emotion regulation: (i) escape reactions from internal-external emotion-eliciting situations and related affective responses; and (ii) attempts of overmodulation of affective states.

Looking at empirical evidence concerning emotion regulation functions of dissociation, Garafolo and colleagues (2022) showed that trait levels of maladaptive emotion regulation interacted with dissociative phenomena in explaining higher levels of feelings of hostility within a male offender sample. Experimental studies (e.g., Ludäscher et al., 2007; Russ et al., 1993) among clinical populations of patients with borderline personality disorder (BPD) highlighted that dissociation was associated with a transient reduction of somato-affective painful experiences. However, there are no studies that have experimentally evaluated how task-evoked integration and segregation processes and related dissociative phenomena could affect emotional functioning, considering both positive and negative affectivity.

1.4. The present study

Starting from the previous theoretical and empirical considerations, the current study aims at experimentally evaluating the consequences of an exposure to different kinds of sensory integration/segregation tasks on dissociative experiences and emotional functioning. Specifically, we administered 3 tasks characterized by specific perceptual characteristics associated to a gradient of complexity of temporal integration/segregation demands (Alvarado et al., 2007; Miller et al., 2017; Van Eijk et al., 2008):

(i) Two Flash Fusion task: unisensory stationary stimuli with low complexity of temporal integration/segregation demands;

(ii) Audio-visual Simultaneity Judgement task: multi-sensory stationary stimuli with medium complexity of temporal integration/segregation demands;

(iii) Audio-Visual Causality task: multi-sensory dynamic stimuli with high complexity temporal integration/segregation demands.

According to evidence-based theoretical frameworks, we hypothesized:

(i) a significant increase of dissociative experiences after the completion of different sensory integration/segregation tasks built to quantitatively measure temporal integration and segregation processes in response to the presentation of stimuli with different gradients of complexity;

(ii) an association between psychophysic indexes (i.e., subjective thresholds of temporal binding capacity) reflecting the degree of multisensory stimuli integration/segregation and pre- vs. post-task changes in dissociative manifestations;

(iii) significant changes in positive (i.e., decrease) and negative (i.e., increase) affective states after the completion of multisensory integration tasks;

(iv) an association between the extent of increases of dissociative experiences and changes in affective states.

We also explored whether pre-task trait levels of dissociation could be associated with psychophysic indexes of integration/segregation processes and the extent of pre- post-task changes in dissociative states. This was tested in order to clarify the nature of dissociation (i.e., dynamic/context-related vs stable/trait-related).

To further corroborate the previous hypotheses, we conducted an independent control experiment administering a task with comparable length and cognitive efforts, which assessed attentional functioning (i.e., attention network test [ANT]; Fan et al., 2002) rather than integration/segregation processes. Accordingly, pre- post-task changes in dissociative experiences and affective states were examined. Different findings between experimental conditions should further support the notion that dissociative experiences are mainly connected to altered integration/segregation processes rather than high-order intentional cognitive linked to levels of consciousness, such as the attentional one (Koch & Tsuchiya, 2007).

2. Materials and methods

2.1. Participants

A total of seventy-five healthy adult participants took part in the study. They had normal or corrected-to-normal vision and reported no history of psychiatric and neurological disorders. From an initial sample size of fifty-four participants who completed the three multi-sensory integration tasks, thirty-six participants were included for the analyses. This selection process was based on the goodness of fit of the logistic fits of the psychometric fits performed (see section 2.3.1 *Psychophysical estimates*). Of the thirty-six included participants, thirty-two [88.8 %] were right-handed and twenty-four (66.6 %) were females. The mean age was 25.14 (SD = 2.55) years old with 17.80 (SD = 1.09) years of education.

A further group of twenty-one (16 [76.4 %] right-handed) voluntary participants were recruited for the administration of ANT. No one was excluded from the study. They had normal or corrected-to-normal vision and reported no history of psychiatric and neurological disorders. Thirteen (61.9 %) subjects were females. The mean age of 27.66 (SD = 5.21) years old with 16.23 (SD = 2.46) years of education.

These groups were not different from each other considering age (U = 271.00; Z = -1.79; *ns*) together with gender ($\chi^2_{(1)} = 0.13$; *ns*) and right-handed ($\chi^2_{(1)} = 1.61$; *ns*) distribution. There was a significant difference between groups with respect to years of education (U = 222.50; Z = 2.75; $p < 0.01$). Accordingly, the analysis explored possible confounding effects of this variable on experimental outcomes.

Ultimately, these groups did not show significant differences in pre-task levels of dissociative states (U = 279.50; Z = -1.54; *ns*) together with positive (U = 295.00; Z = -1.38; *ns*) and negative (U = 335.50; Z = -0.71; *ns*) affective states.

2.2. Procedure

A group of participants completed psychophysical multisensory integration tasks to estimate Temporal Binding Windows (TBWs) in the visual and audio-visual domains. Three tasks were administered to participants using JsPsych (De Leeuw, 2015) and the psychophysics plugin (Kuroki, 2021) in JavaScript: (i) a Two Flash Fusion (2FF) task; (ii) an audio-visual Simultaneity Judgment (SJ) task; (iii) an Audio-Visual Causality (AVC) task, each lasting approximately 10 min. Stimuli were presented on a light gray background on a 13-inch monitor of a portable laptop with a refresh rate of 60 Hz and a resolution of 1440 x 900 pixels. Laptop luminance was kept constant by setting it to the maximum value, and participants were instructed to sit at a distance of an arm's length from the monitor. Participants were given a set of headphones and were instructed to adjust the volume at a comfortable level before the start of the experiment. Participants were instructed to fixate the central fixation point on the monitor during trial presentation. Task order was randomized between participants, and participants could take a short break between tasks.

The control experiment was characterized by the administration of the ANT. The ANT (Fan et al., 2002) was administered using Psychology Experiment Building Language (PEBL) (Mueller & Piper, 2014), which is a free open-source software system developed to design, run, and share behavioral tests.

Participants completed the self-report assessment of dissociation and emotional functioning (see below) before and after the administration of multisensory integration tasks and ANT. Pre and post-task self-report assessment lasted around 10 min. Fig. 1 graphically summarized the structure of the experimental conditions.

2.2.1. Questionnaires

State levels of dissociation

To investigate state levels of dissociation, participants were administered before and after task execution (i.e., sensory integration/segregation or ANT tasks) with an Italian translation of the Clinician-Administered Dissociative States Scale (CADSS) (Bremner et al., 1998a), which includes 19 subject-rated items. Observer-rated items were excluded. The subjective component consists of questions that evaluate dissociative experiences (i.e., amnesia; depersonalization; derealization) at the moment of assessment. The subject endorses one of a range of possible responses: 0 = not at all, 1 = slightly, 2 = moderately, 3 = considerably, 4 = extremely. The items are summed to yield a CADSS total score that was used for the analyses. The original version of the CADSS showed an excellent internal consistency (α = 0.94) (Bremner et al., 1998a) that was replicated in the current samples (N = 36, α = 0.91; N = 21; α = 0.89).

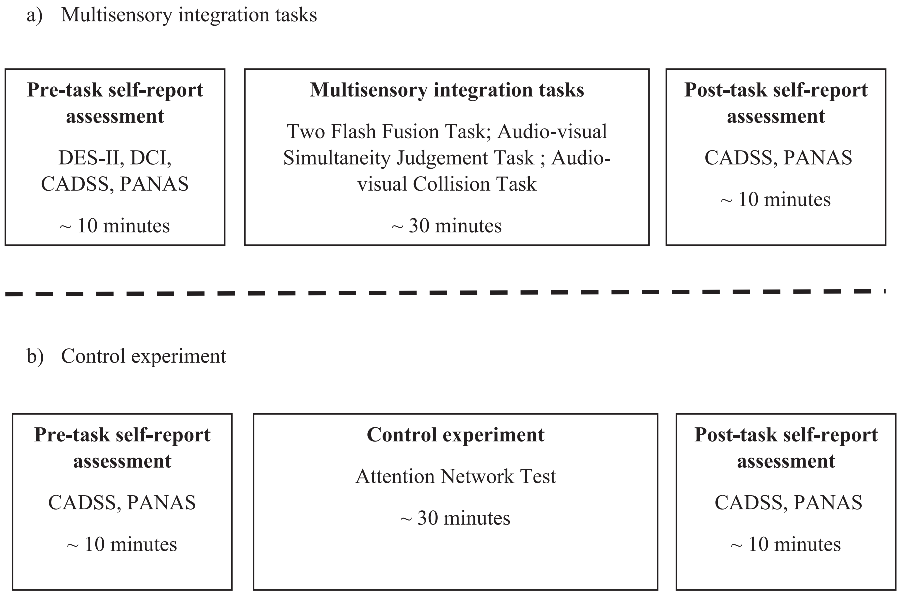

Fig. 1. The structure of experimental conditions.

Trait-based measure of dissociation

To evaluate trait-based measures of dissociative experiences, participants were administered with two questionnaires before sensory integration/segregation tasks: the *Dissociative Experiences Scale-II* (DES-II) *(*Carlson & Putnam, 1993*) and the Detachment and Compartmentalization Inventory (DCI)* (Butler et al., 2019).

The DES-II is a 28-item self-report trait-based measure of dissociative experiences. Items assess the percentage of time that individuals experience several dissociative symptoms. The overall score of the DES-II can range from 0 % to 100 % (thus corresponding to an 11-point Likert scale), and the average score is obtained by adding up the 28 item scores and dividing that total by 28. The DES-II has demonstrated excellent internal consistency, good test–retest reliability, and good convergent validity (e.g., Carlson and Putnam, 1993; van Ijzendoorn and Schuengel, 1996). The Italian version of DES-II was administered (Schimmenti, 2016), which demonstrated adequate psychometric properties in different Italian samples (e.g., Cavicchioli et al., 2023). The DES total score was used in order to test the hypotheses of the study.

The DCI consists of 22 items rated on a 7-point Likert scale. The DCI is composed of the following subscales: (i) 2 validity items, (ii) 10 detachment items, and (iii) 10 compartmentalization items. The detachment and compartmentalization subscales reflect the mean score of related items. The original validation study (Butler et al., 2019) showed excellent internal consistency for detachment ($\alpha = 0.93$) and compartmentalization ($\alpha = 0.96$) subscales. An Italian translation of the DCI was administered, which showed adequate psychometric properties in an Italian sample (Cavicchioli et al., 2023) for both dissociative dimensions (detachment: $\alpha = 0.87$; compartmentalization: $\alpha = 0.90$). The DCI was completed before the exposure to multisensory integration tasks.

Affective states.

Participants were administered with the *Positive and negative affect schedule (PANAS)* (Watson et al., 1988) before and after task execution (i.e., sensory integration/segregation or ANT tasks). The PANAS is a 20-item questionnaire developed for assessing the current positive (Positive Affect, PA) and negative (Negative Affect, NA) affectivity. The PANAS is constituted by 10 positive and 10 negative adjectives. Subjects were asked to rate on a 5-point Likert scale (from 1= “very slightly or not at all” to 5 = “extremely”) how

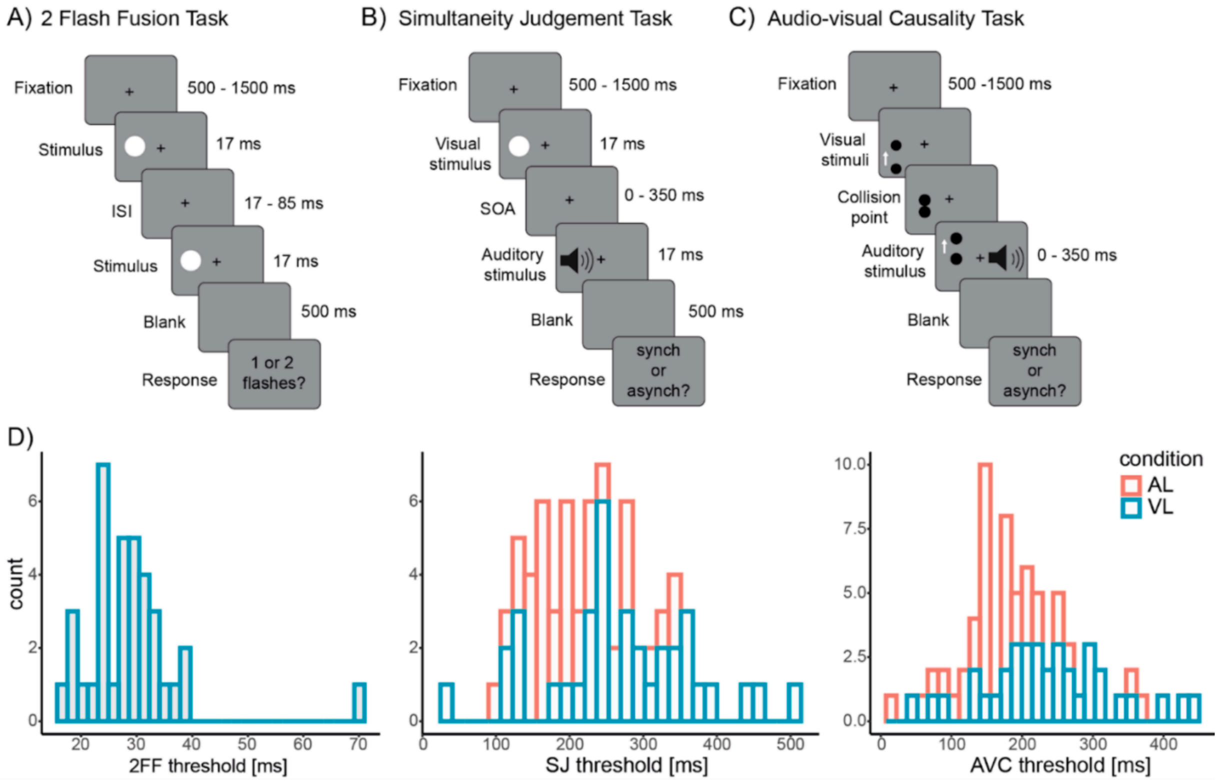

Fig. 2. Structure of sensory integration/segregation task. *Note.* Each trial of the tasks started with a fixation period of random duration (between 500–1500 ms). A) In the 2 Flash Fusion Task, two visual stimuli were flashed in rapid succession, intervalled by an Interstimulus Interval of varying duration. Participants were prompted to respond whether they perceived one or two flashes. B) In the Simultaneity Judgment Task a visual stimulus could be followed (visual leading) or preceded (auditory leading) by an auditory stimulus with a varying Stimulus Onset Asynchrony. C) In the Audio-visual Causality Task, one visual stimulus could move towards another visual stimulus, either moving from the top or the bottom side of the screen. An auditory stimulus could follow (visual leading) or precede (auditory leading) the collision point between the two visual stimuli. For B) and C), the visual leading condition is represented; in both tasks participants were prompted to respond whether the audio-visual events were synchronous or asynchronous. D) Distribution of threshold values (ms) across participants in the three integration tasks. ISI = Interstimulus Interval, SOA = Stimulus Onset Asynchrony, AL = Auditory Leading, VL = Visual Leading.

much they felt as indicated by the 20 adjectives (e.g., active, determined, excited, nervous, scared, distressed, etc.). The sum of the 10 positive and negative adjectives was calculated to provide a total score for PA and NA, respectively. The original validation showed robust internal consistency indexes (.84 ≤ α ≤ 0.90) for both scales, which were stable over a 2-month time period (Watson et al., 1988). We administered the Italian version of PANAS (Terraciano et al., 2003) that highlighted solid psychometric properties (.83 ≤ α ≤ 0.87).

2.2.2. Visual and audio-visual integration tasks

Two flash fusion task

The Two Flash Fusion (2FF) task has been extensively used in the literature to test integration/segregation mechanisms in the visual modality (e.g., Deodato & Melcher, 2024; Deodato et al., 2024; Samaha e Postle, 2015; Ronconi et al., 2017). Each trial of the 2FF task (represented in Fig. 2A) started with a white central fixation point lasting between 500 and 1500 ms. Following, one or two white circles (hereafter called "flashes", ~1 degree of visual angle) flashed for a duration of 1 frame of the monitor (~17 ms), intervalled by an Interstimulus Interval (ISI) ranging between 17 and 85 ms in 5 equally spaced steps. The flashes could either appear at the left or the right side of the fixation point. Participants were prompted to respond with a keyboard press whether they perceived one or two flashes. Two blocks of the 2FF task were presented, intervalled by a short break, for a total of 120 trials (24 trials for each ISI level).

Audio-visual simultaneity Judgement task

Similarly to previous studies (e.g., Marsicano et al., 2022; 2024; Zampini et al., 2005), we used the audio-visual Simultaneity Judgement (SJ) task to assess audio-visual TBWs. Each trial of the task (represented in Fig. 2B) started with a central white fixation point of variable duration between 1000 and 1500 ms. Following, one flash could appear for 2 frames (~32 ms), either at the left or the right side of the fixation point. During stimulus presentation, an auditory stimulus (a beep) was introduced either synchronous or asynchronous to flash presentation, at a variable stimulus onset asynchrony (SOA) ranging between −350 and 350 ms in steps of 70 ms (Marsicano et al., 2022). The auditory stimulus consisted of a pure tone at 750 Hz with a duration of 33 ms. Participants were instructed to report whether they perceived the beep and the circle as simultaneous or not, by keyboard press. Total number of trials amounted to 264 trials (4 blocks), with each level of SOA repeated for 24 trials.

Audio-visual Causality task

Each trial of the audio-visual Causality (AVC) task (represented in Fig. 2A) started with a central white fixation point, presented for a variable duration ranging between 1000 and 1500 ms. Following, two black circles (~1 degree of visual angle) appeared either at the left or the right side of the monitor. One of the two circles was positioned above or below the horizontal midline, and moved in the direction of the other circle, positioned at the horizontal midline, until contact (hereafter defined as "collision point"). During this period, a beep sound was presented, either synchronously or asynchronously with the collision point. To manipulate the perception of causality between the movement of the two circles, we introduced a temporal lag between the beep and the collision point, with 11 equally spaced lags ranging from −350 ms to 350 ms (with 0 ms set as the synchronous condition). This large range was selected because of larger multisensory integration windows with respect to purely visual causality judgements (e.g., Deodato & Melcher, 2022) and to ease the comparison with the Simultaneity Judgement Task. Participants were instructed to report whether they perceived the collision point and the beep as synchronous or asynchronous. We considered "synchronous" responses at non-zero temporal lags as an index of audio-visual perception of causality between consecutive events. A total of 264 trials were presented within 4 blocks, with each possible combination of collision lag and sequence direction repeated for 24 trials.

Attentional network test

The Attentional Network Test (ANT) is designed to evaluate alerting, orienting, and executive attention. It combines the cued reaction time (RT) and the flanker task. The ANT requires participants to determine whether a central arrow points left or right. The arrow appears above or below fixation and may or may not be accompanied by flankers. Efficiency of the three attentional networks is assessed by measuring how response times are influenced by alerting cues, spatial cues, and flankers. The administration of the task lasts around 30 min.

2.3. Data analysis

2.3.1. Psychophysical estimates

Estimates of temporal integration processes were computed using the Quickpsy package in R (Linares & López-Moliner, 2016). Separately for each task, we estimated thresholds and slopes extracted from single subject responses fitted to a logistic function, using the following equation:

$$y = -(1 + exp(-\beta^*(x - \alpha)))$$

where β represents the slope (or steepness) of the curve, α the 0.5 threshold (i.e., the amount of synchrony between the two stimuli needed to elicit a perceived simultaneity in 50 % of the cases), *x* represents the levels of ISI between the two flashes in the case of the 2FF task or SOA between the beep and the flash in the case of the SJ and AVC tasks. For the two audio-visual tasks (i.e. the SJ and the AVC tasks) data were split in a visual-leading (VL) condition (where the visual stimuli precede the beep, represented by SOAs > 0 ms) and an auditory-leading (AL) condition (where the beep precedes the visual stimuli, represented by SOAs < 0 ms). For the VL and AL conditions, we considered the absolute values of thresholds, since in the VL condition the perceived simultaneity decreases as the SOA increases, whereas the thresholds for the AL condition are negative. The fitting procedure for each task and condition resulted in a total of five fits for each participant; for each fit we computed the R^2 adjusted as a measure of the goodness of fit. We excluded from the analysis participants who presented a low goodness of fit (R^2 adjusted < 0.75) in at least one out of the five fits, resulting in the exclusion of 33 % participants out of the initial sample which performed the integration tasks (i.e. fifty-four participants). The extracted parameter, the 0.5 threshold, is commonly interpreted as indexing the amount of onset asynchrony required to elicit a perceived simultaneity between the two stimuli in 50 % of cases.

2.3.2. Statistical analysis

SPSS 22.0 was used for the statistical analyses. According to a violation of the normal distribution (i.e., Kolmogorov-Smirnov test) of the questionnaires' scores, a non-parametric approach was used. Specifically, pre- post-task changes in dissociative experiences and affective states were tested using the Wilcoxon test. The robustness of significance of results was evaluated applying the Monte Carlo simulation using 10,000 independent samples with 99 % confidence interval (CI). The *r* coefficient and its 95 % CI was used as an effect size measure of pre- vs. post-task changes (Field, 2013).

Furthermore, to control pre- and post-tasks changes for baseline levels, a Conover and Iman's rank transform was employed. Accordingly, data were rank transformed, averaged in the case of ties, and then analyzed with the parametric procedures on the ranks resulting in a nonparametric analysis (Conover & Iman, 1981). Specifically, a *t*-test with a covariate (Hedberg & Ayers, 2015) using rank transformed data was computed in order to control CADSS and PANAS change scores for their pre-task levels.

Regression models using rank transformed data were run in order to test different hypotheses. In case of multiple independent variables, multicollinearity was evaluated in order to exclude possible confounding effects associated to interrelationships among independent variables. Criteria proposed by Myers (1990) (i.e., VIF values greater than 10), and Menard (2002) (i.e., tolerance values below 0.2), were applied to detect collinearity problems. A bootstrap methodology (bias corrected and accelerated; Davison, 1997) was applied in computing the significance of predictors. A total of 1,000 bootstrap independent samples were used with $p < 0.05$ (2-tailed).

Regression models evaluated:

(i) the relationships between psychophysics indexes of integration/segregation processes (i.e., thresholds; independent variables) and CADSS/PANAS change scores (i.e., dependent variable);

(ii) the relationships between trait measures of dissociative dimensions (i.e., DES total score and DCI subscales; independent variables) and CADSS/PANAS change scores (i.e., dependent variables);

(iii) the relationship between CADSS change scores (i.e., independent variable) and PANAS change scores (i.e., dependent variable).

3. Results

3.1. Sensory integration/segregation tasks

Table 2 provides a detailed description of descriptive statistics for the thresholds in the three sensory integration/segregation tasks. As anticipated, the proportion of segregation responses increased as a function of the temporal distance between stimuli across all tasks. Accordingly, we obtained a robust fit of the data to the psychometric functions of the 2FF (mean R^2 adjusted = 0.94, SD = 0.07), SJ VL (mean R^2 adjusted = 0.95, SD = 0.06), SJ AL (mean R^2 adjusted = 0.94, SD = 0.07), AVC VL (mean R^2 adjusted: 0.96, SD = 0.05) and AVC AL (mean R^2 adjusted: 0.97, SD = 0.03) tasks. As seen in Fig. 2D, the threshold distribution in the 2FF was consistent with previous reports of visual integration (Deodato & Melcher, 2023; Deodato et al. 2024). This consistency extended to the multisensory distribution for the visual-leading and auditory-leading conditions (Marsicano et al. 2022).

3.1.1. Pre- post-task changes in dissociative experiences and affective states

Table 1 provides descriptive statistics and findings of analyses concerning changes in pre- post-task dissociative experiences and affective states. Results showed a significant moderate-to-large increase of dissociative experiences after the exposure to multi-sensory integration tasks ($t(35) = 6.96$, $p < 0.001$), which was independent of pre-task levels of dissociation states (see Table 1). Similarly, the analyses found a significant moderate-to-large decrease of positive affectivity after the completion of multi-sensory integration tasks independently of baseline levels ($t(35) = -4.23$, $p < 0.001$). No significant changes were observed in negative affectivity ($t(35) = -0.57$, $p = 0.43$). The analyses did not find significant relationships between years of education and pre/post-task scores of CADSS ($\rho_{pre} = -0.06$, $p = 0.74$; $\rho_{post} = 0.23$, $p = 0.17$) and PANAS (positive affect: $\rho_{pre} = 0.11$, $p = 0.54$; $\rho_{post} = -0.18$, $p = 0.29$; negative affect: $\rho_{pre} = -0.32$, $p = 0.06$; $\rho_{post} = 0.11$, $p = 0.51$), together with changes scores in the same dimensions (CADSS: $\rho = 0.33$, $p = 0.05$; PANAS positive affect: $\rho = -0.25$, $p = 0.14$; PANAS negative affect: $\rho = 0.29$, $p = 0.08$).

3.1.2. Predictive role of psychophysic indexes of integration/segregation

Table 2 summarizes results of the regression models, which showed how psychophysic indexes represented significant predictors of changes in pre- post-task dissociative experiences ($F_{(5, 30)} = 3.08$; $p < 0.05$; $R^2 = 0.34$). Specifically, the analysis revealed a significant negative relationship between the SJ-VL threshold and changes in CADSS scores ($\beta = -1.13$, $p < 0.01$). Therefore, subjects with lower audio-visual thresholds in the SJ (specifically for the VL condition) showed a larger increase of dissociative experiences after the completion of multisensory integration tasks. Furthermore, we found a significant positive relationship between the AVC-VL threshold and the extent of changes of dissociative experiences at the end of exposure to multisensory integration tasks ($\beta = 0.9$, $p < 0.01$). Accordingly, subjects who showed higher thresholds of visual colliding stimuli with an auditory stimulus reported larger pre- post-task increases of dissociative experiences. On the contrary, psychophysic indexes were not related to changes in positive affectivity (see

Table 1
Results of multisensory integration tasks ($N = 36$).

	Pre-task		Post-task		Pre- post-task changes		Pre- post-task changes controlling for baseline levels	
	Mean (SD)	Median	Mean (SD)	Median	*Z* (99 % CI p-value Monte Carlo)	*r* (95 % CI)	$t_{(35)}$	*r* (95 % CI)
CADSS	4.66 (6.83)	3.00	6.52 (6.11)	5.00	2.53** (0.008 – 0.01)	0.42 (0.15 – 0.69)	6.96***	0.64 (0.45 – 0.83)
PANAS positive	30.41 (7.65)	30.50	24.75 (8.71)	25.00	−3.38*** (0.000 – 0.001)	−0.56 (−0.77 – −0.35)	−4.23***	0.45 (0.20 – 0.70)
PANAS negative	13.80 (3.90)	13.00	13.38 (4.34)	12.00	−0.39 (0.69 – 0.72)	−0.06 (−0.27 – 0.39)	−0.57	−0.07 (−0.26 – 0.40)
DES total score	1.23 (0.92)	1.05						
DCI detachment	1.44 (0.72)	1.40						
DCI compartmentalization	0.74 (0.56)	0.75						

**$p < 0.01$; ***$p < 0.001$.

Table 2
Regression models.

Independent variables	R^2	$F_{(df)}$	b (95 % bootstrap CI)	β (95 % CI)	Tolerance	VIF
CADSS pre- post-task changes						
	0.34	3.08* $_{(5, 30)}$				
FF threshold (Mean = 0.96; SD = 0.30; Median = 0.91)			0.11 (−0.28 – 0.41)	0.11 (−0.25 – 0.47)	0.68	1.46
SJ-VL threshold (Mean = 0.92; SD = 0.35; Median = 0.89)			−1.13 (−1.57 – −0.74)	−1.13** (−1.76 – −0.50)	0.22	4.39
SJ-AL threshold (Mean = 0.87; SD = 0.27; Median = 0.82)			0.11 (−0.34 – 0.53)	0.11 (−0.30 – 0.53)	0.52	1.91
AVC-VL threshold (Mean = 0.82; SD = 0.32; Median = 0.80)			0.89 (0.29—1.62)	0.90** (0.21—1.58)	0.19	5.09
AVC-AL threshold (Mean = 0.87; SD = 0.36; Median = 0.81)			0.06 (−0.32 – 0.45)	0.06 (−0.30 – 0.42)	0.68	1.46
CADSS pre- post-task changes						
	0.13	1.60$_{(3,.32)}$				
DES total score			0.12 (−0.19 – 0.46)	0.22 (−0.12 – 0.36)	0.56	1.77
DCI detachment			−0.29 (−0.62 – 0.01)	−0.54 (−0.58 – 0.00)	0.38	2.57
DCI compartmentalization			0.07 (−0.19 – 0.31)	0.14 (−0.20 – 0.35)	0.43	2.28
PANAS positive pre- post-task changes						
	0.13	0.87 $_{(5, 30)}$				
FF threshold			−0.18 (−0.65 – 0.29)	−0.18 (−0.60 – 0.23)	0.68	1.46
SJ-VL threshold			0.50 (−0.20—1.06)	0.50 (−0.22—1.23)	0.22	4.39
SJ-AL threshold			−0.16 (−0.69 – 0.40)	−0.16 (−0.64 – 0.31)	0.52	1.91
AVC-VL threshold			−0.49 (−1.16 – 0.24)	−0.49 (−1.28 – 0.28)	0.19	5.09
AVC-AL threshold			−0.11 (−0.53 – 0.20)	−0.11 (−0.53 – 0.30)	0.68	1.46
PANAS positive pre- post-task changes						
	0.07	0.84 $_{(3, 32)}$				
DES total score			−0.22 (−0.70 – 0.13)	−0.27 (−0.61 – 0.16)	0.56	1.77
DCI detachment			0.32 (−0.33—1.06)	0.38 (−0.14 – 0.79)	0.38	2.57
DCI compartmentalization			−0.07 (−0.55 – 0.41)	−0.08 (−0.51 – 0.37)	0.43	2.28
PANAS positive pre- post-task changes						
	0.18	7.60 $_{(1., 34)}$				
CADSS pre- post-task changes			−0.42 (−0.66 – −0.20)	−0.42** (−0.74 – −0.11)	1.00	1.00

*p < 0.05; ***p* < 0.01.
AL = Audio Leading; AVC = Audio-Visual Causality; FF = Flash Fusion; SJ = Simultaneity Judgment; VL = Visual Leading.

Table 2).

3.1.3. Impacts of dissociative experiences on affective states

The regression model (see Table 2) revealed a significant association between pre- post-task changes in dissociative experiences and positive affectivity ($F_{(1, 34)} = 7.60$; $p < 0.01$; $R^2 = 0.18$). Particularly, a greater increase of dissociative experiences was associated with a decrease of positive affectivity after the completion of multisensory integration tasks (β = -0.42, p < 0.01). Fig. 3 graphically summarized main findings of analyses reported in the previous sections.

3.1.4. The role of stable dissociative traits

On the one hand, pre-task CADSS scores were predicted by trait levels of Detachment ($F_{(3, 32)} = 4.19$; $p < 0.05$; $R^2 = 0.28$; $\beta = 0.65$, $p < 0.05$). On the other hand, no trait-based measure of dissociation predicted CADSS post-task scores ($F_{(3, 32)} = 0.60$; $p = 0.62$; $R^2 = 0.05$). Similarly, stable dissociative traits were not related to pre- and post-task of PANAS scores.

Table 2 shows results from the regression model testing the predictive role of dissociative traits on task-dependent results. Results did not show significant relationships between levels of trait measures of dissociation and dynamic changes of dissociative experiences together with positive affectivity after the completion of multisensory integration tasks.

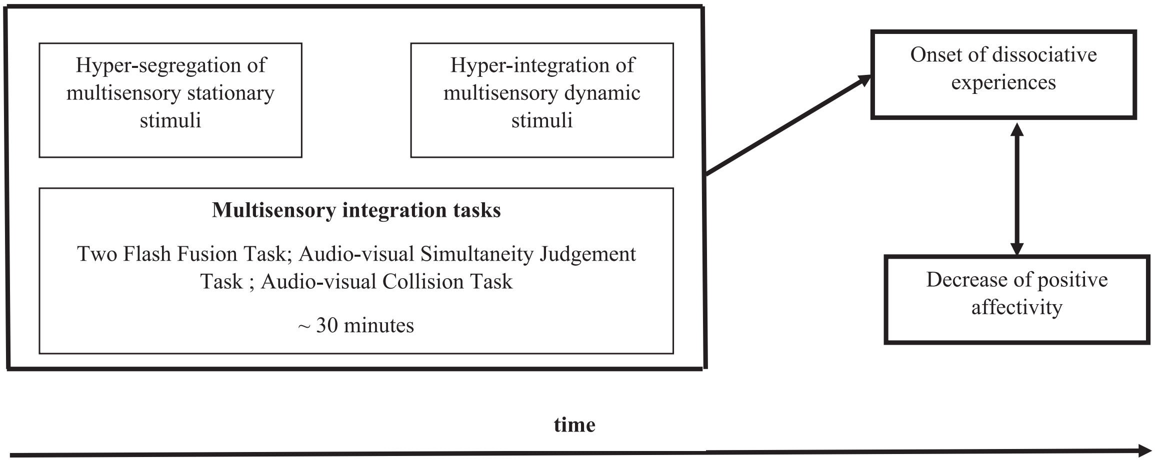

Fig. 3. Integration/segregation processes, dissociative experiences and affective functioning.

3.2. *Control experimental condition*

Table 3 highlights results concerning changes in dissociative experiences and affective states after the completion of the ANT. The analyses found a significant and large decrease of levels of negative affective states at the end of the attentional task ($\beta = -2.73, p < 0.01$). Contrarily, no significant changes were observed in dissociative experiences and positive affectivity. Years of education were not correlated to CADSS (ρ_{pre} = -0.10, p = 0.66; ρ_{post} = -0.02, p = 0.93) and PANAS (positive affect: ρ_{pre} = 0.06, p = 0.80; ρ_{post} = 0.09, p = 0.69; negative affect: ρ_{pre} = -0.10, p = 0.66; ρ_{post} = 0.15, p = 0.52) scores, together with pre-post change scores in the same dimensions (CADSS: ρ = 0.09, p = 0.71; PANAS positive affect: ρ = 0.17, p = 0.46; PANAS negative affect: ρ = 0.33, p = 0.15).

4. Discussion

The current study sought to provide empirical support to clinical and theoretical considerations that view dissociation strictly connected to altered integration/segregation processes of internal/external stimuli (e.g., Scalabrini et al., 2017, 2020; Farina et al., 2019; Farina and Imperatori, 2023; Schimmenti and Sar, 2019), which are considered as the foundations of consciousness (Deco et al., 2015). We tested the effects of an exposure to different multisensory integration demands on dynamic changes of dissociative experiences and their relationships with emotional functioning. To further corroborate this conceptual framework, we conducted an independent control study to show differential effects of high-order attentional efforts on the dynamics of dissociative experiences and affective states.

The current study showed 2 main findings:

(i) the exposure to visual and audio-visual integration demands of varying complexity induced an increase of dissociative experiences. Specifically, we found that the onset of dissociative experiences was predicted by lower audio-visual thresholds (i.e., increased segregation ability) in the SJ task and higher integration thresholds in the AVC task (i.e., higher tendency to integrate the colliding visual stimuli to the auditory stimulus). This might suggest the conclusion that “hyper-segregation” and “hyper-integration” processes (Hornix et al., 2019) of stationary and dynamic multisensory stimuli were respectively involved in the emergence of dissociative experiences. Furthermore, temporal integration efforts affected emotional functioning; specifically, a reduction of positive affectivity was associated to the extent of task-dependent dissociative states;

Table 3
Results of control experimental condition ($N = 21$).

	Pre-task		Post-task		Pre- post-task changes		Pre- post-task changes controlling for baseline levels	
	Mean (SD)	Median	Mean (SD)	Median	*Z* (99 % CI p-value Monte Carlo)	*r* (95 % CI)	$t_{(35)}$	*r* (95 % CI)
CADSS	5.85 (5.19)	4.00	8.80 (8.85)	5.00	1.31 (0.19 – 0.21)	0.29 (−0.20 – 0.58)	1.83	0.21 (−0.20 – 0.62)
PANAS positive	32.57 (5.13)	33.00	31.85 (7.74)	31.00	−0.45 (0.65 – 0.68)	−0.10 (−0.33 – 0.53)	−0.49	−0.06 (−0.37 – 0.49)
PANAS negative	14.52 (4.16)	13.00	12.47 (3.21)	11.00	−2.73** (0.002 – 0.005)	−0.60 (−0.87 – −0.33)	−3.77**	−0.50 (0.17 – 0.83)

**$p < 0.01$.

(ii) results of the control attentional task further supported the hypothesis that dissociative experiences seem to be specifically linked to integration/segregation processes, rather than being generally associated to high-order cognitive processes affecting the level of consciousness.

To our knowledge, this is the first empirical evidence that shows a direct link between multisensory integration/segregation processes and dissociative experiences. Specifically, we provide compelling evidence that the increase of dissociative experiences was not linked to general factors that are common to the completion of psychophysical experiments, such as fatigue and decrease of attention, but was directly linked to the integration/segregation efforts, as shown by the regression analysis. These results are in line with findings from a recent study that reported a relationship between greater visual segregation mechanisms with abnormal perceptual experiences and schizotypal traits (Deodato et al., 2024).

It is interesting to note that only audio-visual psychophysics thresholds, but not unimodal (visual) thresholds predicted changes in dissociative states, suggesting that increased segregation between interconnected sensory areas might be linked to dissociative experiences. More precisely, the implications of reduced thresholds for visual-leading stimuli (i.e., visual stimuli coming slightly before auditory ones) during simultaneity judgments suggested that subjects who effectively discriminated the temporal asynchrony of visual and auditory stimuli presentation with a higher temporal acuity reported higher increases of dissociative experiences after the completion of experimental paradigms. Lower thresholds within an audio-visual simultaneity judgment task reflect how perceptive systems are effective in segregating distinct sensory information (Spence & Squire, 2003; Vroomen & Keetels, 2010, Deodato et al., 2023). This evidence might provisionally support the conclusion that dissociative experiences are associated to a “hyper-segregation” of multisensory (audio-visual) information over time (Hornix et al., 2019), which could be in line with clinical considerations and experimental findings concerning fragmented cognitive-affective-somatic experiences (e.g., traumatic memories) of subjects with high levels of dissociation (e.g., Bedard-Gilligan & Zoellner, 2012; Knox, 2013; Van der Kolk & Fisler, 1995). In a similar vein, Deodato and colleagues argued that greater unisensory temporal segregation could be driven by a disconnection between different sensory parsing processes that causes slower higher-order integration but faster segregation of low-level sensory information, leading to abnormal perceptual experiences (Deodato et al. 2024). Our findings are consistent with this view. Indeed, we found that increased dissociative states were predicted by shorter integration thresholds of simple audio-visual events (SJ task), but, in the complex context of audio-visual causality judgment, higher thresholds were linked to larger increases of dissociative experiences. It has been demonstrated that thresholds and points of subjective simultaneity are sensitive to the spatio-temporal quality of stimuli (Van Eijk et al., 2008) and higher order temporal influences (Deodato & Melcher, 2022). Specifically, a review of empirical studies (Van Eijk et al., 2008) consistently highlighted that visual-motion-leading stimuli were characterized by higher thresholds than stationary visual-leading ones. Kohlrausch and colleagues (2013) suggested that a causal interpretation of the moving stimuli might provide a possible explanation for this shift. Indeed, visual collision promotes the impression that the auditory event (i.e., the beep) is caused by the visual event (i.e., collision between circles). Contrarily, an audio-visual stimulus without visual motion does not suggest a clear causal interpretation, resulting in no significant differences in thresholds and points of subjective simultaneity between audio- and visual-leading presentations. Following these considerations, a heightened sensitivity to causal interpretation of multisensory visual-motion-leading stimuli and related “hyper-integration” (Hornix et al., 2019) of distinct dynamic information might be considered an additional mechanism involved in dissociative experiences. From a clinical perspective, this finding might be in line with distorted implicit appraisals of emotion-eliciting situations associated to dissociative states. Specifically, it has been suggested that the “*defensive mode*” state of mind associated to dissociative phenomena is sustained by automatic and rudimental threat appraisals of a wide range of contextual cues (Morgan III et al., 2001).

Taking these findings and considerations together, dissociative experiences might be viewed in the light of a combination of a “hyper-segregation” of simpler stationary multisensory stimuli and a “hyper-integration” of more complex and dynamic ones. In turn, these results suggest a distinction between low-level and high-level processes of multisensory integration, possibly emerging at different levels of the cortical hierarchy and/or reflecting the recruitment of wider and more complex brain networks (Werner & Noppeney, 2010; Ronconi et al. 2024). From a clinical perspective, the hyper-segregation of simpler static stimuli might capture the inferences of dissociative symptoms (e.g., depersonalization and derealization) on a coherent encoding of salient events (Petersen and Posner, 2012; Conway and Pleydell-Pearce, 2000). On the other hand, the hyper-integration of dynamic stimuli could sustain alterations of threat appraisals linked to positive dissociative symptoms (e.g., intrusive re-experiencing of traumatic memories due to associated mechanisms) (Ehlers et al., 2004). According to the co-existence of altered integration and segregation processes and their synergic relationships (Farina and Imperatori, 2023), evidence-based clinical approaches for dissociation and related conditions (i.e., affect regulation therapy, attachment-based therapy, dialectical behavior therapy, dialectical dynamic therapy, eye movement desensitization and reprocessing, mindfulness-based interventions, psychodynamic-oriented therapies, right brain psychotherapy, sensory-based programs) (Foote and Van Orden, 2016; Fraser, MacKenzie, Versnel, 2017; Liotti, 2013; Mucci, 2018; Şar, 2022; Spermon, Darlington, Gibney, 2010; van der Hart, Nijenhuis, Solomon, 2010; Zerubavel and Messman-Moore, 2015) should dynamically work on these processes promoting a dialectical balance between the improvement of integration among mental functions, experiences and self-states together with a reinforcement of an effective segregation between memory/life-history-related mental states and present-moment experiences.

In accordance with our hypothesis and effects of dissociation on emotional functioning, we found a significant impact of the exposure to sensory integration/segregation efforts and related dissociative experiences on the reduction of positive affectivity. There is consistent evidence that supports a robust association between positive affectivity and extroversion (i.e., the tendency to engage in external arousing behaviors such as social experiences, novelty, changes) (e.g., Gross et al., 1998; Rusting & Larsen, 1997). Accordingly, a reduction of positive affectivity in connection with the emergence of dissociative reactions could experimentally support clinical evidence (Bromberg, 2009; Putnam, 1992) and quantitative self-report findings (Cavicchioli et al. 2021) that have sustained a key disengagement function of dissociation from the external (e.g., derealization) and internal (e.g., depersonalization) world. The impact of dissociation on the reduction of positive affective states was also in line with dissociative emotional numbing (e.g., low arousal non-agitated dysphoria or anhedonia) (Frewen and Lanius, 2006; Lanius et al., 2012), which was further demonstrated administering other experimental paradigms for inducing dissociation and related modification of emotional responses (Shin Goldstein, and Pick, 2019). The indirect impact of sensory integration/segregation efforts on positive affectivity through the increase of dissociative experiences might be also in line with some neurobiological models of dissociation (Lanius et al., 2010) and related phenomena (e.g., dissociative stupor and freezing; Hagenaars et al., 2014; Roelofs, 2017) that have suggested core mechanisms of emotional shutdown, which are felt as a lack of affective states rather than an increase of negative emotionality (e.g., Frewen & Lanius, 2006; Litz et al., 2002). The implications of dissociation in the modulation of affective responses were further corroborated from other neuroscientific data (for a *meta*-analysis see: Cavicchioli et al., 2023). Specifically, it was found that clinical conditions characterized by high levels of dissociation (i.e., BPD, somatoform disorders, PTSD and dissociative disorders) (Lyssenko et al., 2018) highlighted altered patterns of automatic brain responses to the presentation of emotion-eliciting stimuli. The most relevant evidence included an extended brain network composed of: (i) reduced amygdala and parahippocampal gyrus responses (i.e., encoding of emotional-eliciting events) (Dolan & Vuilleumier, 2003; Fusar-Poli et al., 2009); (ii) reduced insula responses (i.e., lack of integration of body sensations, impulse, arousal, cognitive features, and subjective experiences of emotional reactions) (Gasquoine, 2014; Wiens, 2005); (iii) heightened cingulate cortex and middle frontal gyrus activity (i.e., top-down cognitive control of emotions) (Morawetz et al., 2017).

These considerations might also provide a possible explanation of the result concerning no significant pre- post-task changes in negative affectivity.

The lack of significant associations between trait measures of dissociation with task-evoked integration/segregation processes and related changes in dissociative states, could provisionally suggest distinct latent processes for contextual-based dissociation (e.g., peritraumatic dissociation; Lensvelt-Mulders et al., 2008) and structural dissociation (Nijenhuis & Den Boer, 2009; Van der Hart et al., 2006). On the one hand, alterations of integration/segregation processes might represent key features of dynamic states of dissociation. On the other hand, a stable dissociation could be mainly ascribed to a disruption of structural foundations of mind-brain (e.g., volume of brain regions, white matter integrity, neuroinflammation), rather than processes involved in the emergence of consciousness (e.g., functional connectivity), as reported in severe PTSD populations (e.g., Hori & Kim, 2019; Li et al., 2023; Roydeva & Reinders, 2021).

Ultimately, the results of the control experiment allow us to conclude that the emergence of dissociative experiences is mainly linked to the previously mentioned alterations of integration/segregation processes rather than the effects of high-order attentional efforts or more domain-general factors such as time-on-task, sustained attention, etc. The distinction between these mechanisms was also corroborated by different consequences on affective functioning. Indeed, the prolonged intentional control of attention significantly reduces the intensity of negative affectivity in accordance with evidence-based top-down models of emotion regulation (Ochsner et al., 2002, 2009; McRae et al., 2012 Sheppes & Levin, 2013).

Despite these promising results some limitations must be discussed. First, it would have been ideal that each subject completed both experimental conditions (i.e., multisensory integration tasks and the ANT) in different occasions in order to effectively demonstrate the key role of altered integration/segregation processes in the emergence of dissociative states; thus, it is desirable that future studies replicate the current findings by employing a cross-over design. Second, future studies with larger sample sizes should be carried out in order to empirically evaluate whether multisensory hyper-integration and hyper-segregation of different kinds of stimuli (i.e., static vs dynamic) are distinctly associated to specific dissociative phenomena (e.g., hyper-integration: depersonalization, derealization; hyper-segregation: dissociative amnesia) as postulated by the tripartite model proposed by Farina and Imperatori (2023). The current sample sizes did not allow us to explore how the emergence of dissociative phenomena might impact specific positive (e.g., interested; proud; enthusiastic, attentive) and negative (e.g., ashamed; guilt, afraid) affective states. Accordingly, further replication studies should investigate these aspects, especially considering their possible implications for clarifying specific clinical dynamics across different disorders characterized by high levels of dissociation (e.g., post-traumatic stress disorder [PTSD], complex PTSD, borderline personality disorder) (Ford and Courtois, 2021).

Third, the lack of association between trait measure of dissociation with sensory integration/segregation performances and related increases of dissociative reactions could be partially ascribed to the small sample size that did not allow to effectively capture the dimensionality of dissociative traits and their relations with state-dependent reactions. Therefore, future studies should test the relationships between trait and state levels of dissociation, especially in response to multisensory integration demands, among lager samples characterized by a higher variability of dissociative levels compared to the current non-clinical sample, also including subjects affected from clinical conditions ascribed to the dissociative spectrum (e.g., dissociative disorders, PTSD, borderline personality disorder) (Cavicchioli et al., 2023; Lyssenko et al., 2018). Looking at the clinical dissociative spectrum, future studies should also systematically evaluate how different adverse experiences might affect integration/segregation processes linked to dissociative phenomena characterizing PTSD subtypes in the light of specific brain organizations linked to different traumatic experiences (relational vs non-relational) (Scalabrini et al., 2024).

Despite these limitations, this is the first study that provides preliminary experimental support to theoretical and clinical frameworks that view dissociation in the light of basic alterations of temporal integration/segregation processes. Specifically, the current study suggests the emergence of dissociative experiences in association with a “hyper-segregation” of simpler stationary multisensory stimuli and a “hyper-integration” of complex dynamic multisensory stimuli promoting causal inference. Future research among clinical populations characterized by high levels of dissociation should be carried out to clarify how these processes might be involved in the development and maintenance of these disorders.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

CRediT authorship contribution statement

Marco Cavicchioli: Writing – review & editing, Writing – original draft, Formal analysis, Conceptualization. **Alessia Santoni:** Writing – review & editing, Writing – original draft, Software, Methodology, Formal analysis. **Francesco Chiappetta:** Investigation, Data curation. **Michele Deodato:** Writing – review & editing, Writing – original draft, Software, Methodology. **Giuseppe Di Dona:** Software, Methodology, Formal analysis. **Andrea Scalabrini:** Writing – review & editing, Writing – original draft. **Federica Galli:** Writing – review & editing. **Luca Ronconi:** Writing – review & editing, Writing – original draft, Supervision.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

References

Allen, J. G. (2001). *Traumatic Relationships and Serious Mental Disorders*. New York, NY: John Wiley and Sons.
Alvarado, J. C., Vaughan, J. W., Stanford, T. R., & Stein, B. E. (2007). Multisensory versus unisensory integration: Contrasting modes in the superior colliculus. *Journal of neurophysiology, 97*(5), 3193–3205.
Bayne, T., Chalmers, D., 2003. The Unity of Consciousness (1857–1857). University of Arizona.
Bedard-Gilligan, M., & Zoellner, L. A. (2012). Dissociation and memory fragmentation in post-traumatic stress disorder: An evaluation of the dissociative encoding hypothesis. *Memory, 20*(3), 277–299.
Bernstein, E. M., & Putnam, F. W. (1986). Development, reliability, and validity of a dissociation scale. *The Journal of Nervous and Mental Disease, 174*(12), 727–735.
Butler, C., Dorahy, M. J., & Middleton, W. (2019). The Detachment and Compartmentalization Inventory (DCI): An assessment tool for two potentially distinct forms of dissociation. *Journal of Trauma & Dissociation, 20*(5), 526–547.
Bremner, J. D., Krystal, J. H., Putnam, F. W., Southwick, S. M., Marmar, C., Charney, D. S., & Mazure, C. M. (1998). Measurement of dissociative states with the clinician-administered dissociative states scale (CADSS). *Journal of traumatic stress, 11*, 125–136.
Bremner, J. D., Vermetten, E., Southwick, S. M., Krystal, J. H., & Charney, D. S. (1998). Trauma, Memory, and Dissociation: An Integrative Formulation. *American Psychiatric Association Press*, 365–402.
Bromberg, P. M. (2009). Multiple self-states, the relational mind, and dissociation: A psychoanalytic perspective. In P. F. Dell, & J. A. O'Neil (Eds.), *Dissociation and the dissociative disorders: DSM-V and beyond* (pp. 637–652). Routledge/Taylor & Francis Group.
Brown, R. J. (2006). Different types of "dissociation" have different psychological mechanisms. *J. Trauma & Dissociation, 7*(4), 7–28.
Carlson, E. B., & Putnam, F. W. (1993). An update on the dissociative experiences scale. *Dissociation: progress in the dissociative disorders*.
Carlson, E. A., Yates, T. M., & Sroufe, L. A. (2009). Dissociation and development of the self. In P. F. Dell, & J. A. O'Neil (Eds.), *Dissociation and the Dissociative Disorders: DSM-V and beyond* (pp. 39–52). Routledge/Taylor & Francis Group.
Cavicchioli, M., Ogliari, A., Maffei, C., Mucci, C., Northoff, G., & Scalabrini, A. (2023). Neural responses to emotional stimuli across the dissociative spectrum: Common and specific mechanisms. *Psychiatry and Clinical Neurosciences, 77*(6), 315–329.
Cavicchioli, M., Scalabrini, A., Northoff, G., Mucci, C., Ogliari, A., & Maffei, C. (2021). Dissociation and emotion regulation strategies: A meta-analytic review. *Journal of Psychiatric Research, 143*, 370–387.
Conover, W. J., & Iman, R. L. (1981). Rank transformations as a bridge between parametric and nonparametric statistics. *Amer. Statist., 35*(3), 124–129.
Conway, M. A., & Pleydell-Pearce, C. W. (2000). The construction of autobiographical memories in the self-memory system. *The Psychological Review, 107*(2), 261–288.
Craig, A. D. (2002). How do you feel? Interoception: The sense of the physiological condition of the body. *Nature reviews neuroscience, 3*(8), 655–666.
Coons, P.M., 1996. Depersonalization and derealization. In: Michelson, L.K., Ray, W.L., (Eds.), Handbook of Dissociation. Springer, New York, NY, pp. 291–305.
Dalenberg, C. J., & Paulson, K. (2009). The case for the study of "normal" dissociation processes. In P. F. Dell, & J. A. O'Neil (Eds.), *Dissociation and the Dissociative Disorders: DSM–V and beyond* (pp. 145–154). New York, NY: Taylor & Francis.
Davison, A. C. (1997). *Bootstrap methods and their application* (Vol. 1). New York, NY: Cambridge University Press.
Deco, G., Tononi, G., Boly, M., & Kringelbach, M. L. (2015). Rethinking segregation and integration: Contributions of whole-brain modelling. *Nature Reviews Neuroscience, 16*(7), 430–439.
Deodato, M., & Melcher, D. (2022). The effect of perceptual history on the interpretation of causality. *Journal of vision, 22*(11), 13. https://doi.org/10.1167/jov.22.11.13
Deodato, M., & Melcher, D. (2023). Correlations between Visual Temporal Resolution and Individual Alpha Peak Frequency: Evidence that Internal and Measurement Noise Drive Null Findings. *Journal of cognitive neuroscience, 36*(4), 590–601. https://doi.org/10.1162/jocn_a_01993
Deodato, M., Seeber, M., Mammeri, K., Michel, C. M., & Vuilleumier, P. (2024). Combined effects of neuroticism and negative emotional context on spontaneous EEG dynamics. *Social Cognitive and Affective Neuroscience, 19*(1). https://doi.org/10.1093/scan/nsae012
Dixon, P., & Di Lollo, V. (1994). Beyond visible persistence: An alternative account of temporal integration and segregation in visual processing. *Cognitive Psychology, 26*(1), 33–63. https://doi.org/10.1006/cogp.1994.1002
Dolan, R. J., & Vuilleumier, P. (2003). Amygdala automaticity in emotional processing. *Annals of the New York Academy of Sciences, 985*(1), 348–355.
Ehlers, A., Hackmann, A., & Michael, T. (2004). Intrusive re-experiencing in post-traumatic stress disorder: Phenomenology, theory, and therapy. *Memory, 12*(4), 403–415.
Eisen, M. L., & Carlson, E. B. (1998). Individual differences in suggestibility: Examining the influence of dissociation, absorption, and a history of childhood abuse. *Appl. Cognit. Psychol.: The Official Journal of the Society for Applied Research in Memory and Cognition, 12*(7), S47–S61.
Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of cognitive neuroscience, 14*(3), 340–347.

Farina, B., & Imperatori, C. (2023). Are traumatic disintegration, detachment, and dissociation separate pathogenic processes related to attachment trauma? A working hypothesis for clinicians and researchers. *Psychopathology*, 1–12.
Farina, B., Liotti, M., & Imperatori, C. (2019). The role of attachment trauma and disintegrative pathogenic processes in the traumatic-dissociative dimension. *Frontiers in psychology, 10*, 933.
Field, A. (2013). *Discovering statistics using IBM SPSS statistics*. sage.
Foa, E. B., & Riggs, D. S. (1995). Posttraumatic stress disorder following assault: Theoretical considerations and empirical findings. *Current Directions in Psychological Science, 4*(2), 61–65.
Foote, B., & Van Orden, K. (2016). Adapting dialectical behavior therapy for the treatment of dissociative identity disorder. *American Journal of Psychotherapy, 70*, 343–364.
Ford, J. D., & Courtois, C. A. (2021). Complex PTSD and borderline personality disorder. *Borderline personality disorder and emotion dysregulation, 8*(1), 16.
Frewen, P. A., & Lanius, R. A. (2006). Toward a psychobiology of posttraumatic self-dysregulation: Reexperiencing, hyperarousal, dissociation, and emotional numbing. *Annals of the New York Academy of Sciences, 1071*(1), 110–124.
Fusar-Poli, P., Placentino, A., Carletti, F., Allen, P., Landi, P., Abbamonte, M. A. R. T. A., & Politi, P. L. (2009). Laterality effect on emotional faces processing: ALE meta-analysis of evidence. *Neuroscience letters, 452*(3), 262–267.
Gasquoine, P. G. (2014). Contributions of the insula to cognition and emotion. *Neuropsychology review, 24*, 77–87.
Gross, J. J., Sutton, S. K., & Ketelaar, T. (1998). Relations between affect and personality: Support for the affect-level and affective-reactivity views. *Personality and social psychology bulletin, 24*(3), 279–288.
Hagenaars, M. A., Oitzl, M., & Roelofs, K. (2014). Updating freeze: Aligning animal and human research. *Neuroscience & Biobehavioral Reviews, 47*, 165–176.
Hedberg, E. C., & Ayers, S. (2015). The power of a paired t-test with a covariate. *Social science research, 50*, 277–291.
Holmes, E. A., Brown, R. J., Mansell, W., Fearon, R. P., Hunter, E. C., Frasquilho, F., & Oakley, D. A. (2005). Are there two qualitatively distinct forms of dissociation? A review and some clinical implications. *Clinical Psychology Review, 25*(1), 1–23.
Hori, H., & Kim, Y. (2019). Inflammation and post-traumatic stress disorder. *Psychiatry and clinical neurosciences, 73*(4), 143–153.
Hornix, B. E., Havekes, R., & Kas, M. J. (2019). Multisensory cortical processing and dysfunction across the neuropsychiatric spectrum. *Neuroscience & Biobehavioral Reviews, 97*, 138–151.
Koch, C., & Tsuchiya, N. (2007). Attention and consciousness: Two distinct brain processes. *Trends in cognitive sciences, 11*(1), 16–22.
Kohlrausch, A., van Eijk, R., Juola, J. F., Brandt, I., & van de Par, S. (2013). Apparent causality affects perceived simultaneity. *Attention, Perception, & Psychophysics, 75*, 1366–1373.
Knox, J. (2013). The mind in fragments: The neuroscientific, developmental, and traumatic roots of dissociation and their implications for clinical practice. *Psychoanalytic Inquiry, 33*(5), 449–466.
Lanius, R. A., Brand, B., Vermetten, E., Frewen, P. A., & Spiegel, D. (2012). The dissociative subtype of posttraumatic stress disorder: Rationale, clinical and neurobiological evidence, and implications. *Depression and anxiety, 29*(8), 701–708.
Lanius, R. A., Vermetten, E., Loewenstein, R. J., Brand, B., Schmahl, C., Bremner, J. D., & Spiegel, D. (2010). Emotion modulation in PTSD: Clinical and neurobiological evidence for a dissociative subtype. *Am. J. Psychiatr., 167*(6), 640–647.
Lensvelt-Mulders, G., van Der Hart, O., van Ochten, J. M., van Son, M. J., Steele, K., & Breeman, L. (2008). Relations among peritraumatic dissociation and posttraumatic stress: A meta-analysis. *Clinical psychology review, 28*(7), 1138–1151.
Li, J., Tong, L., Schock, B. C., & Ji, L. L. (2023). Post-traumatic stress disorder: Focus on neuroinflammation. *Molecular Neurobiology, 60*(7), 3963–3978.
Liotti, G. (2004). Trauma, dissociation, and disorganized attachment: Three strands of a single braid. *Psychotherapy: Theory, Research, Practice, Training, 41*(4), 472–486.
Liotti, G. (2009). Attachment and dissociation. In P. Dell, & J. A. O'Neil (Eds.), *Dissociation and Dissociative Disorders: DSM-V and beyond* (pp. 53–65). New York: Routledge.
Liotti, G. (2013). Disorganized/disoriented attachment in the psychotherapy of the dissociative disorders. In *Attachment theory* (pp. 343–363). Routledge.
Litz, B. T., Litz, B. T., & Gray, M. J. (2002). Emotional numbing in posttraumatic stress disorder: Current and future research directions. *Australian & New Zealand Journal of Psychiatry, 36*(2), 198–204.
Ludäscher, P., Bohus, M., Lieb, K., Philipsen, A., Jochims, A., & Schmahl, C. (2007). Elevated pain thresholds correlate with dissociation and aversive arousal in patients with borderline personality disorder. *Psychiatry research, 149*(1–3), 291–296.
Lyssenko, L., Schmahl, C., Bockhacker, L., Vonderlin, R., Bohus, M., & Kleindienst, N. (2018). Dissociation in psychiatric disorders: A meta-analysis of studies using the dissociative experiences scale. *American Journal of Psychiatry, 175*(1), 37–46.
Maldonado, J. R., & Spiegel, D. (1998). Trauma, dissociation, and hypnotizability. In J. D. Bremner, & C. R. Marmar (Eds.), *Trauma, Memory, and Dissociation* (pp. 57–106). Washington, DC: American Psychiatric Press.
Marsicano, G., Bertini, C., & Ronconi, L. (2024). Alpha-band sensory entrainment improves audiovisual temporal acuity. *Psychonomic Bulletin & Review, 31*, 874–885. https://doi.org/10.3758/s13423-023-02388-x
Marsicano, G., Cerpelloni, F., Melcher, D., et al. (2022). Lower multisensory temporal acuity in individuals with high schizotypal traits: A web-based study. *Scientific Reports, 12*, 2782. https://doi.org/10.1038/s41598-022-06503-1
McRae, K., Misra, S., Prasad, A. K., Pereira, S. C., & Gross, J. J. (2012). Bottom-up and top-down emotion generation: Implications for emotion regulation. *Social cognitive and affective neuroscience, 7*(3), 253–262.
Menard, S. (2002). Applied logistic regression analysis. Sage university paper series on quantitative applications in the social sciences. Thousand Oaks07–106.
Miller, R. L., Stein, B. E., & Rowland, B. A. (2017). Multisensory integration uses a real-time unisensory–multisensory transform. *Journal of Neuroscience, 37*(20), 5183–5194.
Morawetz, C., Bode, S., Derntl, B., & Heekeren, H. R. (2017). The effect of strategies, goals and stimulus material on the neural mechanisms of emotion regulation: A meta-analysis of fMRI studies. *Neuroscience & Biobehavioral Reviews, 72*, 111–128.
Mucci, C. (2018). *Borderline Bodies: Affect Regulation Therapy for Personality Disorders (Norton Series on Interpersonal Neurobiology)*. New York: WW Norton & Company.
Mueller, S. T., & Piper, B. J. (2014). The psychology experiment building language (PEBL) and PEBL test battery. *Journal of Neuroscience Methods, 222*, 250–259.
Myers, R. H. (1990). *Classical and modern regression with applications*. Boston: Duxbury Press.
Naragon-Gainey, K., McMahon, T. P., & Chacko, T. P. (2017). The structure of common emotion regulation strategies: A meta-analytic examination. *Psychological Bulletin, 143*(4), 384–427.
Nijenhuis, E. R. (2001). Somatoform dissociation: Major symptoms of dissociative disorders. *J. Trauma & Dissociation, 1*(4), 7–32.
Nijenhuis, E. R., & Den Boer, J. A. (2009). Psychobiology of traumatisation and trauma related structural dissociation of the personality. In P. F. Dell, & J. A. O'Neil (Eds.), *Dissociation and the Dissociative Disorders: DSM–V and beyond* (pp. 337–367). New York, NY: Routledge.
Nijenhuis, E. R. S., Spinhoven, P., Van Dyck, R., Van der Hart, O., & Vanderlinden, J. (1996). The development and the psychometric characteristics of the Somatoform Dissociation Questionnaire (SDQ-20). *The Journal of Nervous and Mental Disease, 184*, 688–694.
Nijenhuis, E. R. S., & Van der Hart, O. (1999). Somatoform dissociative phenomena: A Janetian perspective. In J. M. Goodwin, & R. Attias (Eds.), *Splintered Reflections: Images of the Body of Trauma* (pp. 89–127). New York, NY: Basic Books.
Northoff, G., Wainio-Theberge, S., & Evers, K. (2020). Is temporo-spatial dynamics the "common currency" of brain and mind? In quest of "spatiotemporal neuroscience". *Physics of Life Reviews, 33*, 34–54.
Ochsner, K. N., Bunge, S. A., Gross, J. J., & Gabrieli, J. D. (2002). Rethinking feelings: An FMRI study of the cognitive regulation of emotion. *Journal of cognitive neuroscience, 14*(8), 1215–1229.
Ochsner, K. N., Ray, R. R., Hughes, B., McRae, K., Cooper, J. C., Weber, J., & Gross, J. J. (2009). Bottom-up and top-down processes in emotion generation: Common and distinct neural mechanisms. *Psychological science, 20*(11), 1322–1331.

Parsons, B. D., Gandhi, S., Aurbach, E. L., Williams, N., Williams, M., Wassef, A., & Eagleman, D. M. (2013). Lengthened temporal integration in schizophrenia. *Neuropsychologia, 51*(2), 372–376.
Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience, 35*, 73–89.
Pöppel, E. (2010). Perceptual identity and personal self: Neurobiological reflections. In T. Maruszewski, M. Fajkowska, & M. M. Eysenck (Eds.), *Personality from biological, cognitive, and social perspectives* (pp. 75–82). Clinton Corners, New York: Eliot Werner Publications.
Putnam, F. W. (1992). Discussion: Are alter personalities fragments or figments? *Psychoanalytic Inquiry: A Topical Journal for Mental Health Professionals, 12*, 95–111.
Roelofs, K. (2017). Freeze for action: Neurobiological mechanisms in animal and human freezing. *Philosophical Transactions of the Royal Society B: Biological Sciences, 372*(1718), 20160206.
Ronconi, L., Balestrieri, E., Baldauf, D., & Melcher, D. (2024). Distinct Cortical Networks Subserve Spatio-temporal Sampling in Vision through Different Oscillatory Rhythms. *Journal of cognitive neuroscience, 36*(4), 572–589. https://doi.org/10.1162/jocn_a_02006
Ronconi, L., Melcher, D., & Franchin, L. (2020). Investigating the role of temporal processing in developmental dyslexia: Evidence for a specific deficit in rapid visual segmentation. *Psychonomic bulletin & review, 27*(4), 724–734. https://doi.org/10.3758/s13423-020-01752-5
Ronconi, L., Oosterhof, N. N., Bonmassar, C., & Melcher, D. (2017). Multiple oscillatory rhythms determine the temporal organization of perception. *Proceedings of the National Academy of Sciences of the United States of America, 114*(51), 13435–13440. Doi: 10.1073/pnas.1714522114.
Ronconi, L., Vitale, A., Federici, A., Mazzoni, N., Battaglini, L., Molteni, M., & Casartelli, L. (2023). Neural dynamics driving audio-visual integration in autism. *Cerebral cortex (New York, N.Y. : 1991)*, *33*(3), 543–556. Doi: 10.1093/cercor/bhac083.
Roydeva, M. I., & Reinders, A. A. (2021). Biomarkers of pathological dissociation: A systematic review. *Neuroscience & Biobehavioral Reviews, 123*, 120–202.
Russ, M. J., Shearin, E. N., Clarkin, J. F., Harrison, K., & Hull, J. W. (1993). Subtypes of self-injurious patients with borderline personality disorder. *The American journal of psychiatry, 150*(12), 1869–1871.
Rusting, C. L., & Larsen, R. J. (1997). Extraversion, neuroticism, and susceptibility to positive and negative affect: A test of two theoretical models. *Personality and individual differences, 22*(5), 607–612.
Santoni, A., Melcher, D., Franchin, L., & Ronconi, L. (2024). Electrophysiological signatures of visual temporal processing deficits in developmental dyslexia. *Psychophysiology, 61*(2), e14447.
Şar, V. (2022). The dialectical dynamic therapy of trauma. *Journal of Trauma & Dissociation, 23*, 339–355.
Scalabrini, A., Cavicchioli, M., Benedetti, F., Mucci, C., & Northoff, G. (2024). The nested hierarchical model of self and its non-relational vs relational posttraumatic manifestation: An fMRI meta-analysis of emotional processing. *Molecular Psychiatry*, 1–14.
Scalabrini, A., Cavicchioli, M., Fossati, A., & Maffei, C. (2017). The extent of dissociation in borderline personality disorder: A meta-analytic review. *J. Trauma & Dissociation, 18*(4), 522–543.
Scalabrini, A., Mucci, C., Esposito, R., Damiani, S., & Northoff, G. (2020). *Dissociation as a disorder of integration–On the footsteps of Pierre Janet* (p. 109928). Psychiatr: Prog. Neuro Psychopharmacol. Biol.
Scalabrini, A., Mucci, C., Angeletti, L. L., & Northoff, G. (2020). The self and its world: A neuro-ecological and temporo-spatial account of existential fear. *Clinical Neuropsychiatry, 17*(2), 46–58.
Schore, A. N. (2009). Relational trauma and the developing right brain. *Annals of the New York Academy of Sciences, 1159*(1), 189–203.
Schimmenti, A. (2016). Dissociative experiences and dissociative minds: Exploring a nomological network of dissociative functioning. *Journal of Trauma & Dissociation, 17*(3), 338–361.
Schimmenti, A., & Sar, V. (2019). A correlation network analysis of dissociative experiences. *J. Trauma & Dissociation, 20*(4), 402–419.
Seth, A. K., & Bayne, T. (2022). Theories of consciousness. *Nature Reviews Neuroscience, 23*(7), 439–452.
Sheppes, G., & Levin, Z. (2013). Emotion regulation choice: Selecting between cognitive regulation strategies to control emotion. *Frontiers in human neuroscience, 7*, 179.
Spence, C., & Squire, S. (2003). Multisensory integration: Maintaining the perception of synchrony. *Current Biology, 13*(13), R519–R521.
Stevenson, R. A., Ghose, D., Fister, J. K., Sarko, D. K., Altieri, N. A., Nidiffer, A. R., & Wallace, M. T. (2014). Identifying and quantifying multisensory integration: A tutorial review. *Brain topography, 27*, 707–730.
Terraciano, A., McCrae, R. R., & Costa, P. T., Jr. (2003). Factorial and construct validity of the Italian Positive and Negative Affect Schedule (PANAS). *European Journal of Psychological Assessment, 19*(2), 131–141.
Van der Hart, O., Nijenhuis, E., Steele, K., & Brown, D. (2004). Trauma-related dissociation: Conceptual clarity lost and found. *Australian & New Zealand Journal of Psychiatry (Carlton), 38*(11–12), 906–914.
Van der Hart, O., Nijenhuis, E., & Steele, K. (2006). *The Haunted Self: Structural Dissociation and the Treatment of Chronic Traumatization*. New York, NY: Norton.
Van der Kolk, B. A., & Fisler, R. (1995). Dissociation and the fragmentary nature of traumatic memories: Overview and exploratory study. *Journal of traumatic stress, 8*, 505–525.
Van der Kolk, B. A., & McFarlane, A. C. (Eds.). (1996). *Traumatic Stress: the Effects of Overwhelming Experience on Mind, Body, and Society*. New York: Guilford Press.
Van Eijk, R. L., Kohlrausch, A., Juola, J. F., & van de Par, S. (2008). Audiovisual synchrony and temporal order judgments: Effects of experimental method and stimulus type. *Perception & psychophysics, 70*, 955–968.
Van der Kolk, B. (2014). *The Body Keeps the Score: Mind*. Penguin UK: Brain and Body in the Transformation of Trauma.
van Dijke, A., van der Hart, O., Ford, J. D., van Son, M., van der Heijden, P., & Bühring, M. (2010). Affect dysregulation and dissociation in borderline personality disorder and somatoform disorder: Differentiating inhibitory and excitatory experiencing states. *Journal of Trauma & Dissociation, 11*(4), 424–443.
Vroomen, J., & Keetels, M. (2010). Perception of intersensory synchrony: A tutorial review. *Attention, Perception, & Psychophysics, 72*(4), 871–884.
Wang, J., Lu, J., Zhang, X., Jia, L., & Wang, C. (2022). Collision Narrows the Temporal Binding Window of Multisensory Integration. *Advances in Cognitive Psychology, 18*(1).
Wang, L., Lin, L., & Ren, J. (2023). The characteristics of audiovisual temporal integration in streaming-bouncing bistable motion perception: Considering both implicit and explicit processing perspectives. *Cerebral Cortex, 33*(24), 11541–11555.
Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology, 54*(6), 1063–1070.
Werner, S., & Noppeney, U. (2010). Distinct functional contributions of primary sensory and association areas to audiovisual integration in object categorization. *The Journal of neuroscience : the official journal of the Society for Neuroscience, 30*(7), 2662–2675. https://doi.org/10.1523/JNEUROSCI.5091-09.2010
Wiens, S. (2005). Interoception in emotional experience. *Current opinion in neurology, 18*(4), 442–447.
Wolff, A., Berberian, N., Golesorkhi, M., Gomez-Pilar, J., Zilio, F., & Northoff, G. (2022). Intrinsic neural timescales: Temporal integration and segregation. *Trends in cognitive sciences, 26*(2), 159–173.
World Health Organization, 2018. International Classification of Diseases for Mortality and Morbidity Statistics (11th Revision).
Zampini, M., Guest, S., Shore, D. I., et al. (2005). Audio-visual simultaneity judgments. *Perception & Psychophysics, 67*, 531–544. https://doi.org/10.3758/BF03193329
Zelazo, P. D., & Cunningham, W. A. (2007). Executive function: Mechanisms underlying emotion regulation. In J. J. Gross (Ed.), *Handbook of Emotion Regulation* (pp. 135–158). The Guilford Press.
Zerubavel, N., & Messman-Moore, T. L. (2015). Staying present: Incorporating mindfulness into therapy for dissociation. *Mindfulness, 6*, 303–314.
Zhou, H. Y., Cai, X. L., Weigl, M., Bang, P., Cheung, E. F., & Chan, R. C. (2018). Multisensory temporal binding window in autism spectrum disorders and schizophrenia spectrum disorders: A systematic review and meta-analysis. *Neuroscience & Biobehavioral Reviews, 86*, 66–76.
Zhou, H. Y., Cheung, E. F., & Chan, R. C. (2020). Audiovisual temporal integration: Cognitive processing, neural mechanisms, developmental trajectory and potential interventions. *Neuropsychologia, 140*, Article 107396.