“I can’t tell whether it’s my hand”: a pilot study of the neurophenomenology of body representation during the rubber hand illusion in trauma-related disorders

Daniela Rabellino1†, Sherain Harricharan2†, Paul A. Frewen1,3,4, Dalila Burin5, Margaret C. McKinnon6,7,8 and Ruth A. Lanius1,2,4 *

1Department of Psychiatry, University of Western Ontario, London, ON, Canada; 2Department of Neuroscience, University of Western Ontario, London, ON, Canada; 3Department of Psychology, University of Western Ontario, London, ON, Canada; 4Imaging Division, Lawson Health Research Institute, London, ON, Canada; 5SAMBA (SpAtial, Motor & Bodily Awareness) Research Group, Psychology Department, University of Turin, Turin, Italy; 6Mood Disorders Program, St. Joseph’s Healthcare, Hamilton, ON, Canada; 7Department of Psychiatry and Behavioural Neurosciences, McMaster University, Hamilton, ON, Canada; 8Homewood Research Institute, Guelph, ON, Canada

Background: Early traumatic experiences are thought to be causal factors in the development of trauma-related dissociative experiences, including depersonalization and derealization. The rubber hand illusion (RHI), a well-known paradigm that measures multi-sensorial integration of a rubber hand into one’s own body representation, has been used to investigate alterations in the experience of body ownership and of body representation. Critically, however, it has never been studied in individuals with trauma-related disorders.

Objective: To investigate body representation distortions occurring in trauma-related disorders in response to the RHI.

Method: The RHI was administered to three individuals with the dissociative subtype of posttraumatic stress disorder (PTSD), and subjective, behavioral, cardiovascular and skin conductance responses were recorded.

Results: Participants’ subjective experiences of the RHI were differentiated and complex. The illusion was induced following both synchronous and asynchronous brushing and variably evoked subjective distress, depersonalization and derealization experiences, tonic immobility, increased physiological arousal and flashbacks.

Conclusions: The present findings point towards the RHI as a strong provocation stimulus that elicits individual patterns of symptom presentation, including experiences of distress and dissociation, in individuals with trauma-related disorders, including the dissociative subtype of PTSD.

Keywords: Body ownership; dis-embodiment; multi-sensorial integration; autonomic arousal; depersonalization; derealization; consciousness

Highlights of the article

- The rubber hand illusion (RHI) elicits distress, tonic immobility, depersonalization and derealization, and autonomic responses in individuals with trauma-related disorders, including the dissociative subtype of posttraumatic stress disorder (PTSD).
- RHI effects related to body misrepresentation may trigger altered experiences related to body ownership.
- The RHI represents a promising paradigm for studying the neurophenomenology of body distortion in individuals experiencing trauma-related altered states of consciousness (TRASC).

Responsible Editor: Chris Brewin, University College London, UK.

*Correspondence to: Ruth A. Lanius, Department of Psychiatry, University of Western Ontario, 339 Windermere Road, London, ON, Canada, Email: Ruth.Lanius@lhsc.on.ca

For the abstract or full text in other languages, please see Supplementary files under ‘Article Tools’

Received: 19 July 2016; Revised: 20 October 2016; Accepted: 24 October 2016; Published: 21 November 2016

†Joint first authorship.
Dissociation, frequently associated with psychological trauma (Brand, Loewenstein, & Spiegel, 2013; Dalenberg et al., 2012), describes the experience of psychological detachment from normal perceptions of one’s self or surroundings resulting in an altered state of consciousness (Diagnostic and Statistical Manual of Mental Disorders-5 [DSM-5], American Psychiatric Association [APA], 2013). In recognition of this strong association between dissociation and trauma, a dissociative subtype of posttraumatic stress disorder (PTSD), focusing on the presence of symptoms of depersonalization and derealization was recently added to the DSM-5 (Lanius, Bethany, Vermetten, Frewen, & Spiegel, 2012). Frewen and Lanius (2015) described trauma-related dissociation and altered states of consciousness in the context of a 4-dimensional model (“4-D model”) that classifies symptoms of trauma-related psychopathology into those that occur within normal waking consciousness versus those that are intrinsically dissociative and associated with trauma-related altered states of consciousness (TRASC) across four dimensions: one’s experience of (1) time, (2) thought, (3) body and (4) emotion (also see Lanius, 2015).

Traumatized individuals that experience TRASC related to the experience of their body are described by the 4-D model as experiencing depersonalization symptoms, specifically, those involving partial or full disembodiment (Frewen & Lanius, 2015; Sierra & Berrios, 1998). Partial disembodiment occurs when one experiences a disconnection between particular parts of one’s body and the greater gestalt of one’s embodied sense of self, such as in limb disownership and paralysis. Such disowned body parts are thus experienced as “non-self,” and are often described as feeling “strange” or “different from expected” (Frewen & Lanius, 2015). By contrast, in cases of full disembodiment, one feels disconnected from the whole of one’s body, as in an out-of-body experience (Blanke & Metzinger 2009; Frewen & Lanius, 2015). Although the 4-D model focuses on TRASC, depersonalization symptoms can also be observed in psychiatric and neurologic disorders outside of a trauma context. For example, depersonalization/derealization disorder, migraines and seizures are frequently associated with altered bodily representation (Alper et al., 1997; APA, 2013; Baker et al., 2003; Blau, 1992; Kenna & Sedman, 1965).

The rubber hand illusion (RHI; Botvinick & Cohen, 1998) is a well-described experimental paradigm that can be used to invoke alterations in the experience of the body schema through simultaneous visual and proprioceptive feedback (Ehrsson, Holmes, & Passingham, 2005; Longo, Schütz, Kammers, Tsakiris, & Haggard, 2008). Here, the participant is instructed to stare at a rubber hand while his/her actual hand is hidden from view during simultaneous brushing of both the rubber and actual hand. This manipulation can create a temporary distortion in the physical schema of the body, with a subjective feeling of ownership of the rubber hand in approximately 70–80% of tested participants, where participants perceive the rubber hand as their own (Botvinick & Cohen, 1998; Ehrsson, Spence, & Passingham, 2004). Accordingly, the RHI serves as an important experimental paradigm to study the neurophenomenological bases of the experience of conscious embodiment, allowing for investigation of the correlation between psychological identity and one’s sense of body ownership (Longo & Haggard, 2012).

To date, no studies have examined response to the RHI among individuals with trauma-related disorders and dissociative symptoms. Here, we provide RHI case reports of three traumatized patients with a diagnosis of the dissociative subtype of PTSD with comorbid dissociative disorder not otherwise specified (DDNOS). We hypothesized that, given their chronic tendency toward experiences of TRASC of their body and the high likelihood of the RHI inducing changes in body representation, these participants might readily experience a pronounced RHI. We also examined whether experiences of the RHI might lead to other forms of dissociation and TRASC (e.g., derealization symptoms and TRASC of time, thought and emotion) and measured arousal and perceived distress through self-reports and physiological recordings (skin conductance response, heart rate and heart-rate variability).

Ethics
This study was approved by the local research ethics board. All names have been changed to protect patient privacy. All patients consented to their inclusion in the report and had the opportunity to review the manuscript prior to its submission.

Methods
Psychological assessment
All patients were diagnosed with PTSD based on the Clinician-Administered PTSD Scale (CAPS) (cut-off for PTSD ≥ 50; Blake et al., 1995). The Structured Clinical Interview for Dissociative Disorders (SCID-D; Steinberg, Cicchetti, Buchanan, & Hall 1993) was conducted to assess dissociative disorders, and the Structured Clinical Interview for DSM-IV (SCID-I; First, Spitzer, Gibbon, & Williams, 2002) was administered in order to document any other current Axis I psychiatric disorders. Prior to the experiment, the patients were also administered a battery of questionnaires:

- The Scale of Bodily Connection (SBC) (Price & Thompson, 2007) was used to assess bodily awareness on a Likert scale from 0 (not at all) to 4 (all of the time).
The Dissociation Tension Scale (DSS-4) (Stiglmayr, Schmahl, Brenner, Bohus, & Ebner-Priemer, 2009) was used to compare the patient’s perception of dissociative states associated with bodily consciousness and psychological identity, based on a Likert scale of 0 (none) to 9 (very strong).

The PTSD Checklist for DSM-5 (PCL-5) (Weathers et al., 2013) and appended items assessing TRASC (Frewen, Brown, Steuwe, & Lanius, 2015) were administered to assess state PTSD and dissociative symptoms on a Likert scale of 0 (not at all) to 4 (extremely).

See Tables 1–3 for a summary of obtained scores on these measures.

**Physiological measurements**

The Nexus-10 & Bio Trace + physiological sensors technology (MindMedia b.v., The Netherlands; Kurumbanshi, Kapur, & Bajaj, 2014) was utilized to obtain heart rate variability (HRV) from a finger blood-volume pulse sensor, and finger galvanic skin conductance (GSC) was also acquired using the same system. Two measures of HRV were calculated using BioTrace software: the standard deviation of interbeat intervals (SDNN), which has shown to be an indicator of overall HRV (Guédon-Moreau et al., 2012; Saul, Albrecht, Berger, & Cohen 1987; Tan, Wang, & Ginsberg, 2013), and the root mean square differences in interbeat intervals (RMSDD), which is thought to be an indicator of vagal outflow and thus reflects parasympathetic nervous system activation (PNS; Bigger et al., 1989; Kleiger, Stein, & Bigger, 2005). By contrast, GSC is a measure of sweat gland activity and is thought to be indicative of sympathetic nervous system (SNS) arousal (Darrow, 1936; Montagu & Coles, 1966). In order to observe baseline physiological measures, a 2-min resting state assay was performed prior to the experiment. When analyzing HRV data, artifacts were both automatically (using a $920\%$ difference based on the previous interbeat interval) and manually (via visual inspection) removed to account for environmental and biological noise (Xu & Schuckers, 2001).

Please see Fig. 3 for a summary of physiological measures obtained.

**RHI procedure**

Following standard methods (Burin et al., 2015), the RHI paradigm consisted of a black box (60 cm × 40 cm × 20 cm)

---

**Table 1. Psychometric assessments**

| Psychometric assessments | Stephanie | Dawn | Michelle |
|--------------------------|-----------|------|----------|
| CAPS total score         | 61        | 99   | 68       |
| Dissociative subtype$^a$ | Yes       | Yes  | Yes      |
| SCID/D                   | DDNOS – in partial remission | DDNOS | DDNOS – in partial remission |
| SBC$^b$                  | 2.86      | 1.83 | 2.9      |
| Tension rating$^c$       | Pre = 7   | Post = N/A$^a$ | Pre = 9 | Post = 9 | Pre = 8 | Post = 3 |
| DSS-4 (mean)             | Pre = 4.25 | Post = N/A$^a$ | Pre = 5 | Post = 6.75 | Pre = 0 | Post = 0 |
| State PCL-5 TRASC (sum scores) | N/A | N/A | Pre = 22 | Post = 23 | Pre = 4 | Post = 3 |
| SCID-I                   | – past major depressive disorder | – recurrent major depressive disorder | – undifferentiated somatoform disorders |
|                         |           | – trauma-related eating disorder | – current agoraphobia without panic |
|                         |           |                               | – past recurrent major depressive disorder |
|                         |           |                               | – past alcohol and substance dependence |
|                         |           |                               | – past panic disorder with agoraphobia |

$^a$Assessed through CAPS, depersonalization and derealization items (score ≥ 4, frequency-intensity); $^b$general population average score = 3.645 ± 0.645 (Price & Thompson, 2007); $^c$measured by the DSS-4, item on state tension; $^d$the participant was not able to fill the DSS-4 after the task; $^e$healthy population range = 0 < DSS-4 < 1 (Barnow et al., 2012). CAPS: Clinician Administered PTSD Scale; DDNOS: dissociative disorder not otherwise specified; DSS-4: Dissociation Tension Scale – short version; PCL-5: PTSD Checklist for DSM-5; pre: pre-task; post: post-task; SBC: Scale of Bodily Connection; SCID-D: Structured Clinical Interview for Dissociative Disorders; SCID-I: Structured Clinical Interview for DSM-IV.
with a perpendicular panel dividing it in half (30 cm × 40 cm × 20 cm), arranged such that the patient’s real hand would be hidden and only the life-like rubber hand would be within the patient’s view. The patient wore a white cape on her body to ensure that only the rubber hand was in view and was oriented such that the patient’s shoulder was in line with the rubber hand. Both the real and rubber hand were positioned with fingers pointing forward and palms facing down, with a distance between the real and the rubber hand of approximately 15 cm.

For the illusion experiment, the right hand (dominant hand for all three subjects) was brushed with a paintbrush for two trials, each lasting 2 min, as described by Costantini and Haggard (2007). Only one hand was tested as this procedure induced depersonalization and derealization symptoms in some participants during pilot testing of the current study. During the first trial, the administrator initiated asynchronous brushing, alternately brushing the index fingers of the rubber hand and the actual hand. The trial order was alternated between participants.

Prior to each trial, the box was covered with a flat lid, and a ruler (in centimeters) was placed on the lid. The participant was then asked to report the number on the ruler that corresponded to her perceived index finger (Burin et al., 2015). This procedure was repeated six times, changing randomly the position of the ruler each time. The same exercise was performed after the trial to determine proprioceptive drift (see Fig. 2 for pre- and post-trial individual proprioceptive drift). The absolute drift was obtained by subtracting the average post-trial estimations from the average pre-trial estimations for each subject (Botvinick & Cohen, 1998). A nine-item questionnaire created from Botvinick and Cohen’s (1998) original RHI study was administered verbally to the patient after each trial to identify the subjective perception of the illusion (see individual scores in Fig. 1).

### Table 2. Pre- and post-task scores of trauma-related altered states of consciousness for Dawn and Michelle

| State PCL-5 TRASC* | Dawn | Michelle |
|--------------------|------|----------|
| #1: Flashbacks of traumatic events | 3 | 3 | 0 | 2 |
| #2: Altered sense of time | 3 | 3 | 0 | 0 |
| #3: Marked loss of emotional feeling | 2 | 4 | 0 | 0 |
| #4: Feeling what you are experiencing is not real | 3 | 3 | 0 | 0 |
| #5: Out of body experience | 2 | 2 | 0 | 0 |
| #6: Feeling like a part of your body is not your own | 2 | 2 | 0 | 0 |
| #7: Identity confusion | 1 | 2 | 1 | 0 |
| #8: Divided or multiple senses of self | 3 | 2 | 3 | 1 |
| #9: Loss of time | 3 | 2 | 0 | 0 |
| #10: Hearing voices | 0 | 0 | 0 | 0 |

*Examples of questions:  
#1: “Do you feel as if a traumatic event from the past is happening in the present? If so, do you feel like you are reliving the event rather than only remembering it?”  
#2: “Do you feel as if you have little sense of the passage of time? Or do you feel as if time has slowed down, speeded up, or seems like it is stopped or standing still?”

### Table 3. Pre- and post-task scores of the DSS-4

| DSS-4 | Stephanie | Dawn | Michelle |
|-------|-----------|------|----------|
| #1: Current inner tension. | 7 | N/A | 9 | 9 | 8 | 3 |
| #2: My body or parts of my body do not belong to me. | 7 | N/A | 2 | 7 | 0 | 0 |
| #3: I have problems hearing, for example, I hear sounds that are close to me as if they are coming from far away. | 3 | N/A | 6 | 7 | 0 | 0 |
| #4: I have the impression that other people, objects, or the world around me are not real. | 7 | N/A | 6 | 7 | 0 | 0 |
| #5: I have the impression that my body or a part of it is insensitive to pain. | 0 | N/A | 6 | 6 | 0 | 0 |
\textbf{Fig. 1.} Answers from all three case report subjects to the nine-question post-trial questionnaire administered following each asynchronous and synchronous trial. Each question is evaluated on a Likert scale spanning from $-3$ (complete disagreement) and $+3$ (complete agreement). The first three questions assess the illusion effect, whereas the last six serve as control questions. This plot reveals that all subjects endorsed the subjective perception of the illusion following the synchronous trial, whereas only Stephanie endorsed the perception of the illusion following the asynchronous trial. It is important to note that for both Stephanie and Dawn, the asynchronous trial was performed first and the synchronous trial second, whereas for Michelle, the order was reversed.

\textbf{Fig. 2.} The diagram depicts the participant’s objective perception of the rubber hand illusion, as it shows the participant’s perception of her real index finger location relative to the location of the rubber hand both before and after the asynchronous and synchronous brushing trials. The lines for each participant are presented in chronological order as both Stephanie and Dawn received the asynchronous trial first, whereas Michelle received the asynchronous trial second. All participants perceived a drift towards the rubber hand after both asynchronous and synchronous brushing trials.
Case report A: Stephanie

History and diagnosis
Stephanie is a 50-year-old woman who experienced emotional abuse from a young age. Stephanie's father was largely absent due to alcoholism while her mother was emotionally neglectful. She was sexually abused by her brother and was repeatedly gang-raped as an adolescent. As an adult, Stephanie spent nearly 8 years as a psychiatric inpatient setting before she was referred to a trauma specialty service with a diagnosis of PTSD (dissociative subtype), a DDNOS and major depressive disorder. During previous treatment, Stephanie described depersonalization experiences involving a lack of body ownership of her hands, for example, during mindful body-scan exercises. She also described out-of-body experiences that occurred during recall of traumatic memories. After undergoing trauma therapy for several years, however, Stephanie no longer met criteria for PTSD, DDNOS, and depression, and her overall level of functioning improved significantly. Indeed, over the past 4 years, Stephanie had worked productively as a teacher in Canada and more recently abroad. Unfortunately, however, she experienced a relapse of PTSD and depersonalization and derealization.

Fig. 3. Physiological data. The graph depicts the heart rate variability (left y-axis) and galvanic skin conductance (GSC) obtained for both Stephanie and Dawn during each stage of the RHI experiment. (a) Standard deviation of interbeat intervals (SDNN) is an overall indicator of total HRV, whereas root mean square of interval differences (RMSDD) is an indicator of vagal outflow, a proxy for parasympathetic activity. Both Stephanie and Dawn experienced overall decreases in SDNN and RMSDD during the RHI experiment. Stephanie experienced gradual declines in both SDNN and RMSDD. Dawn showed higher SDNN and RMSDD values than Stephanie but still showed a gradual decline in RMSDD. Dawn experienced a sharp decrease from rest in SDNN after the asynchronous (asynch) trial, but instead showed a slight increase after the synchronous (synch) brushing. (b) GSC is an indicator of sympathetic arousal, as it measures sweat gland activity. In both Stephanie and Dawn, there was a progressive increase in skin conductance throughout the experiment. In Stephanie, there was a significantly greater increase following the synchronous trial when compared to the increase observed after the asynchronous trial.

Citation: European Journal of Psychotraumatology 2016, 7: 32918 - http://dx.doi.org/10.3402/ejpt.v7.32918
symptoms several months prior to the present RHI assessment upon witnessing a grandfather physically abusing his grandson and sought further short-term treatment.

Observations during RHI

Prior to the experiment, Stephanie reported an experience of high inner tension and dissociative symptoms related to body disownership and derealization on the DSS-4 (see Table 3). The intensity of these experiences increased, however, during administration of the RHI. Indeed, simply placing the rubber hand within Stephanie’s view caused immediate anxiety, where she commented “It looks real” and pointed out its resemblance to her own hands during experiences of partial disembodiment: “[It] looks like when my hands are detached … it looks like it’s detached from my body.” Following the first experimental trial with asynchronous brushing, the RHI was induced, where Stephanie described “This is kind of bizarre” and that, when her actual hand was stroked, it felt as if the experimenter “was stroking this one [the rubber hand] … and the thing moves [the rubber hand].” She noted further that “I don’t like that it moves. It’s … It’s like it’s attached itself to me.” Stephanie related that “I can’t tell whether it’s my hand or somebody else’s hand, or who it belongs to.” Interestingly Stephanie further described the experience as “like being dissociated” and that she experienced an associated feeling of distress accompanied by upset stomach. She also indicated that she was “losing focus” and noted some derealization symptoms: “I’m having trouble figuring out what’s real and what’s not.” She indicated further that her real hand felt like it was turning rubbery and that the rubber hand, or who it belongs to. Interestingly, Stephanie also indicated that over the period of anxiety provoked by the RHI, she experienced tonic immobility: “You can’t move, there’s nothing you can do to make it stop … I think there is also the fear that if you try, something will happen, so you’ve just got to let it play out.” Finally, Stephanie showed a progressive decrease in HRV (both for the SDNN and RMSDD) and a progressive increase in GSC, suggestive of decreases in PNS activity and increases in SNS activity (see Fig. 3).

Case report B: Dawn

Patient history and diagnosis

Dawn is a 64-year-old woman who was adopted at age three into a household with an absent father and an emotionally abusive mother that neglected her and made her feel inferior to her siblings. Her adoptive mother repeatedly told Dawn that she wished Dawn had never been born and never existed. Eventually, Dawn was referred to a trauma specialty clinic after being diagnosed with what were considered intractable symptoms of PTSD (dissociative subtype) and depression related to her childhood abuse. She presently experiences a reduction in her symptoms of PTSD, depersonalization, derealization, and depression and works in the mental health field.

Observations during RHI

Prior to the RHI, Dawn reported a high inner tension but comparably few disembodiment symptoms on the DSS-4 (Table 3). She did, however, report difficulty identifying and expressing emotions as well as perceiving bodily sensations related to her emotional state on the SBC (Table 1). On the SBC questionnaire administered prior to the experiment, Dawn indicated that she often feels frozen or numb during uncomfortable situations, and that it was difficult to listen to information from her body related to her emotional state. Her overall poor body awareness was therefore considered a potential susceptibility factor for the RHI (Tsakiris, Tajadura-Jiménez, & Costantini, 2011).

As was the case with Stephanie, Dawn experienced distress and dissociation immediately upon seeing the rubber hand, reporting that she was having “difficulty...
staying present.” This increased during the asynchronous trial, which Dawn described as “kind of disconnecting ... Part way through it was harder to figure out which [hand] was which.” Interestingly, Dawn was able to attribute her experience of “disconnection” to a dissociation between visual and tactile perception: “it was more difficult to actually feel it than it was to see it. Um, there was a disconnect there.” Behavioral testing confirmed Dawn’s experience of a proprioceptive drift towards the rubber hand after the asynchronous trial (post-trial > pre-trial, \( M = 5.33 \pm 2.42 \) cm; see Fig. 2). However, during administration of the post-trial questionnaire, the subjective strength of the illusion was closer to neutral scores, all within the range \(-1 \) to \(+1\) on the Likert scale (Fig. 2). Sensing her discomfort, the interviewer asked how she was feeling and, like Stephanie, Dawn described an experience of tonic immobility, specifically stating that her body felt frozen and unable to move. She also experienced a difficulty “staying present” that she attributed to a difficulty having to “stay in one position” during the experiment. Asked if she felt she was unable to move she described a sensation: “Kind of from the neck down.” Following administration of the synchronous trial, Dawn experienced an intensified fear response that she attributed to the RHI, specifically, her hand “taking on the form of the rubber hand ... I guess that it seems so real.”

Critically, Dawn continued to experience tonic immobility through the duration of the session, to the point of requiring assistance removing the experimental dress (white cape) at the conclusion of the experiment. She reported later that she could only feel her fingertips throughout the experiment, but not her full hands, and she was observed to press down on her hands with her fingertips, an action she reported served to “fight the disconnection and try to stay present.” Interestingly, during debriefing, she also noted that her sense of time and space had become altered during the experiment, which she thought lasted only 10–15 min whereas the session actually required approximately 90 min to complete. She also reported that the partial disembodiment she experienced in her hand prompted a vulnerability to a full (whole body) out-of-body experience: “There were points [in time] I could feel the out-of-body stuff, which I don’t feel very often. I had to fight the urge to ‘leave’ [my body].”

The experimenter administered the post-trial estimations of index finger location, and they demonstrated a proprioceptive drift towards the rubber hand (post-trial > pre-trial, \( M = 2.5 \pm 0.84 \) cm; see Fig. 2), although lower than after the asynchronous trial. The pre-measurements were already closer to the rubber hand, carrying over from the asynchronous trial, suggesting that Dawn did not come back from her drift experienced during the asynchronous trial. On the post-trial questionnaire (Fig. 1), however, Dawn this time reported a stronger subjective perception of the RHI. Like Stephanie, Dawn also explicitly reported the feeling of the rubber hand as becoming her own right hand, instead of experiencing having more than one right hand. According to the DSS-4 (Table 3), she continued to maintain a high inner tension but felt more disconnected from her body parts. Relative to her autonomic responses, Dawn experienced an overall decrease in HRV, including for SDNN and RMSDD, in conjunction with a progressive increase in GSC (Fig. 3).

Case report C: Michelle

Patient history and diagnosis

Michelle is a 59-year-old woman who experienced multiple instances of childhood physical and sexual abuse occurring between the ages 4 and 18, and who also grew up with a physically and emotionally abusive and neglectful mother. Michelle was also married to an emotionally, physically and sexually abusive man for over 25 years. Michelle has had over 50 psychiatric admissions, lasting from 3 days up to 6 months. She was diagnosed with PTSD (dissociative subtype), DDNOS (in partial remission), major depressive disorder (recurrent) and dysthymia. Her symptoms have become more stable in recent years, and she has not had any psychiatric admissions for 5 years.

Observations during RHI

Michelle reported high inner tension but no disembodiment symptoms on the DSS-4 prior to the experiment (Table 3). On the PCL-5 and TRASC items (Frewen et al., 2015), she indicated feeling “a little bit” of identity confusion (associated with an unstable sense of self) and an experience of multiple, divided senses of self “quite a bit” (see Table 2), findings consistent with her diagnosis of DDNOS.

Due to technical difficulties, physiological data were not collected for this case. Upon being presented with the rubber hand, Michelle experienced an immediate sense of anxiety, commenting: “It’s a little scary, kind of looks a little too real, but kind of feels like it should be my hand there but it’s not ... just makes me feel a little shaky ... a bit like a dead person’s hand.”

In contrast to the protocol order performed in Case Report A and B, for this case we decided to administer the synchronous trial first. After the synchronous trial, Michelle described her experience of the RHI as accompanied by distress: “I want to say scary, but that’s not maybe the word ... It felt like it was my other hand ... it just kind of gave me the creeps.” Her proprioceptive drift (post-trial > pre-trial drift) towards the rubber hand (\( M = 1.40 \pm 2.51 \) cm; see Fig. 2) indicated she had, to some degree, experienced the illusion. Consistent with
this, she endorsed many accompanying subjective percep-
tions of the illusion on the post-trial questionnaire (Fig.
1). Interestingly, when she was asked if the rubber hand
to be the same as her mother’s hand, she stated that it
reminded her of her deceased mother’s hand. Incidentally,
she also noted that, unbeknownst to the investigators, the
testing day occurred on the 1-year anniversary of her
mother’s death.

Following the asynchronous trial, Michelle’s responses
to the post-task questionnaire suggest a less pronounced
RHI (see Fig. 1). However, she continued to perceive the
rubber hand as resembling her mother’s hand. Interestingly,
the difference between pre- and post-trial proprioceptive
drift indicated a larger drift towards the rubber hand in the
asynchronous trial, as compared to the synchronous trial
(post-trial > pre-trial drift, \( M = 2.50 \pm 2.40 \) cm; see Fig. 2).

Michelle also commented generally that the experi-
mental session provoked an increased experience of
flashbacks (see Table 2). This is particularly interesting
given Michelle’s report that the rubber hand resembled
that of her deceased mother, a former perpetrator of her
past traumas. As such, the representation of Michelle’s
own bodily space, when perturbed by the illusion, may
have been experienced as being invaded by her perpe-
trator. Accordingly, her experience that the hand was her
own and the perpetrator’s may have triggered the flash-
backs and distress she experienced during the experiment.
It is noteworthy, however, that Michelle’s reaction to the
RHI may be related to the anniversary of her mother’s
death. Future studies involving larger samples are there-
fore warranted.

Summary and conclusions

Here, we described responses to the presentation of the
RHI among three individuals with the dissociative subtype of
PTSD (D-PTSD) and comorbid DDNOS. The evidence reviewed here strongly suggests that, as
a provocation stimulus, the RHI has the potential to
serve as a potent elicitor of distress, depersonalization,
derealization, tonic immobility and dissociative flash-
backs in persons with D-PTSD. As expected, the RHI
is most pronounced during synchronous relative to
asynchronous brushing, suggesting its partial mediation
trough divergent multisensory perception. Nonetheless,
asynchronous brushing and indeed mere presentation of
the rubber hand was seen to variably evoke subjective
distress and depersonalization and derealization experi-
ences across cases, including an explicit case of traumatic
reminding in Michelle, suggesting that its mechanism of
action may be more multifaceted and complex in trau-
atized individuals than is observed in healthy partici-
pants. Notably, although the asynchronous trial is
generally regarded as a control trial in RHI experiments,
Longo et al. (2008) suggested that this type of brushing can
lead to deafference, where conflicting sensory information
may lead to restricted transmission of this input into the
brain. Given that mind-body connections appear more vulnerable to disruption in traumatized patients with a
history of depersonalization symptoms, conflicting senso-
ry information may predispose these patients to experi-
encing feelings of disembodiment during the RHI
paradigm (Frewen & Lanius, 2015).

In this vein, we would like to underline that each patient
made it explicitly clear that they perceived the rubber
and their actual hands as “coming together.” Here,
it is interesting to note that results of previous studies
investigating the RHI in healthy participants (Moseley,
Gallace, & Spence, 2012) suggested that the rubber hand
substitutes the actual hand of the participant in the
neural representation of one’s own body schema. Indeed,
Moseley et al. (2012) proposed that during the illusion
effect, the cortical representation of the space pertaining
to one’s own hidden hand becomes occupied by the space
containing the rubber hand. As a result, homeostatic
control and sensory processing from the previous space
decreases, as shown by drops in temperature of the real
hidden hand (Moseley et al., 2008). Future studies in
PTSD should therefore also explore changes in tempera-
ture within the real hand during the RHI.

The phenomenology of the RHI experienced by trau-
matized individuals appears differentiated and complex.
Both Stephanie and Dawn reported significant deperso-
nalization and derealization symptoms that were accom-
panied by distress and tonic immobility following the
RHI, which, in turn, were associated with reduced PNS
and increased SNS arousal. We also found that the RHI
may serve as a potent elictor of trauma-related flash-
backs-re-experiencing (Stephanie and Michelle). Finally,
in PTSD patients with prominent dissociative experiences,
we found that the bodily misperception provoked by the
RHI can further alter other dimensions of subjective
consciousness, including time perception (Stephanie) and
identity.

Here, we hypothesize that, among PTSD patients with
dissociative symptoms who do not present with prominent
identity confusion and fragmentation, the RHI, at most,
duces a relatively transient state of partial disembodi-
ment (depersonalization). However, in the presence of
significant identity disturbance, the RHI may also occa-
sion significant ego dissolution, prompt traumatic re-
experiencing, and lead to more marked distress. Further
neurobiological investigation of the RHI in complex
dissociative disorder patients is therefore warranted to
increase our understanding of the neural mechanisms
underlying the conscious embodiment of human self and
its vulnerability to alteration through experimental
manipulation and exposure to traumatic stress. In addi-
tion, future research that includes a comparison group
and larger samples is warranted. The cases presented here offer
further clinical insight into how consciousness can be
compromised when mind and body are disconnected and emphasizes the importance of developing specific psychological treatments for those that experience TRASC.

**Funding statement**

DR was supported by MITACS and Homewood Research Institute.

**Authors’ contributions**

DR, SH, PF and RL designed the study; DR, SH and RL conducted the study and the analyses; all authors contributed to the final manuscript. All authors have read and approved the final version of the manuscript.

**Conflict of interest**

There is no conflict of interest in the present study for any of the authors.

**References**

Alper, K., Devinsky, O., Perrine, K., Luciano, D., Vazquez, B., Pacia, S., & Rhee, E. (1997). Dissociation in epilepsy and conversion nonepileptic seizures. *Epilepsia, 38*(9), 991–997. doi: http://dx.doi.org/10.1111/j.1528-1157.1997.tb01481.x

American Psychiatric Association (APA). (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: Author.

Barnow, S., Limberg, A., Stopsack, M., Spitzer, C., Grabe, H.J., Freyberger, H.J., & Hamm, A. (2012). Dissociation and emotion regulation in borderline personality disorder. *Psychological Medicine, 42*(4), 783–794. doi: http://dx.doi.org/10.1017/S0033291711001917

Baker, D., Hunter, E., Lawrence, E., Medford, N., Patel, M., Senior, C., ... David, A.S. (2003). Depersonalisation disorder: Clinical features of 204 cases. *The British Journal of Psychiatry, 182*(5), 428–433. doi: http://dx.doi.org/10.1192/bjp.182.5.428

Bigger, J.T., Albrecht, P., Steinman, R.C., Rolnitzky, L.M., Fleiss, J.L., & Cohen, R.J. (1989). Comparison of time-and frequency domain-based measures of cardiac parasympathetic activity in Holter recordings after myocardial infarction. *The American Journal of Cardiology, 64*(8), 556–558. doi: http://dx.doi.org/10.1016/0002-9149(89)90436-0

Blake, D.D., Weathers, F.W., Nagy, L.M., Kaloupek, D.G., Gusman, F.D., Charney, D.S., & Keane, T.M. (1995). The development of a clinician-administered PTSD scale. *Journal of Traumatic Stress, 8*(1), 75–90. doi: http://dx.doi.org/10.1007/BF02105408

Blanken, O., & Metzinger, T. (2009). Full-body illusions and minimal phenomenal selfhood. *Trends in Cognitive Sciences, 13*(1), 7–13. doi: http://dx.doi.org/10.1016/j.tics.2008.10.003

Blau, J.N. (1992). Classical migraine: Symptoms between visual aura and headache onset. *The Lancet, 340*(8815), 355–356. doi: http://dx.doi.org/10.1016/0140-6736(92)91415-5

Botvinick, M., & Cohen, J. (1998). Rubber hands “feel” touch that eyes see. *Nature, 391*(6669), 756. doi: http://dx.doi.org/10.1038/37584

Brand, B.L., Loewenstein, R.J., & Spiegel, D. (2013). Disinhibition about dissociation. *Journal of Nervous and Mental Disorders, 201*(4), 353–358. doi: http://dx.doi.org/10.1097/NMD.0b013e31828842dc

Burin, D.; Livelli, A.; Garbarini, F.; Fossataro, C.; Folegatti, A.; Gindri, P.; & Pia, L. (2015). Are movements necessary for the sense of body ownership? Evidence from the rubber hand illusion in pure hemiplegic patients. *PLoS One, 10*(3), e0117155. doi: http://dx.doi.org/10.1371/journal.pone.0117155

Costantini, M., & Haggard, P. (2007). The rubber hand illusion: Sensitivity and reference frame for body ownership. *Consciousness and Cognition, 16*(2), 229–240. doi: http://dx.doi.org/10.1016/j.concog.2007.01.001

Dalenberg, C.J., Brand, B.L., Gleaves, D.H., Dorahy, M.J., Loewenstein, R.J., Cardeña, E., ... Spiegel, D. (2012). Evaluation of the evidence for the trauma and fantasy models of dissociation. *Psychological Bulletin, 138*(3), 550–588. doi: http://dx.doi.org/10.1037/a0027447

Darrow, C.W. (1936). The galvanic skin reflex (sweating) and blood-pressure as preparatory and facilitative functions. *Psychological Bulletin, 33*(2), 73. doi: http://dx.doi.org/10.1037/t0001940

Ehrsson, H.H., Holmes, N.P., &Passingham, R.E. (2005). Touching a rubber hand: Feeling of body ownership is associated with activity in multisensory brain areas. *The Journal of Neuroscience, 25*, 10564–10573. doi: http://dx.doi.org/10.1523/JNEUROSCI.0800-05.2005

Ehrsson, H.H., Spence, C., &Passingham, R.E. (2004). That’s my hand! Activity in premotor cortex reflects feeling of ownership of a limb. *Science, 305*(5685), 875–877. doi: http://dx.doi.org/10.1126/science.1097011

First, M.B., Spitzer, R.L., Gibbon, M., Williams, J.B.W. (2002). *Structured Clinical Interview for DSM-IV Axis I Disorders, Research version, Non–patient Edition (SCID–II/NP)*. New York: Biometrics Research, New York State Psychiatric Institute.

Frewen, PA., Brown, M.F.D., Steuwe, C., & Lanius, R.A. (2015). Latent profile analysis and principal axis factoring of the DSM-5 dissociative subtype. *European Journal of Psychotraumatology, 6*, 26406. doi: http://dx.doi.org/10.3402/ejpt.v6.26406

Frewen, PA., & Lanius, R.A. (2015). *Healing the traumatized self*. New York: W.W. Norton & Company.

Guédon-Moreau, L., Ducrocq, F., Molenda, S., Duhem, S., Salleron, J., Chaudieu, L., ... Vaiva, G. (2012). Temporal analysis of heart rate variability as a predictor of post-traumatic stress disorder in road traffic accidents survivors. *Journal of Psychiatric Research, 46*(6), 790–796. doi: http://dx.doi.org/10.1016/j.jpsychires.2012.02.006

Kenna, J.C., & Sedman, G. (1965). Depersonalization in temporal lobe epilepsy and the organic psychoses. *The British Journal of Psychiatry, 111*(473), 293–299. doi: http://dx.doi.org/10.1192/bjp.111.473.293

Kleger, R.E., Stein, P.K., & Bigger, J.T. (2005). Heart rate variability: Measurement and clinical utility. *Annals of Noninvasive Electrocardiology, 10*(1), 88–101. doi: http://dx.doi.org/10.1111/j.1542-474X.2005.10010.x

Kurumbanshi, S., Kapur, A., & Bajaj, P. (2014). Wireless monitoring of physiological data using Nexus-10 & Biotrace. *International Journal of Electronics & Communication, 2*(1), 8–15.

Lanius, R.A. (2015). Trauma-related dissociation and altered states of consciousness: a call for clinical, treatment, and neuroscience research. *European Journal of Psychotraumatology, 6*, 1–9. doi: http://dx.doi.org/10.3402/ejpt.v6.27905

Lanius, R.A., Bethany, 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. doi: http://dx.doi.org/10.1002/an.21389

Longo, M.R., & Haggard, P. (2012). What is it like to have a body? *Current Directions in Psychological Science, 21*(2), 140–145. doi: http://dx.doi.org/10.1177/0963721411453982

Longo, M.R., Schütz, F., Kammers, M.P., Tsakiris, M., & Haggard, P. (2008). What is embodiment? A psychometric approach.
Montagu, J.D., & Coles, E.M. (1966). Mechanism and measurement of the galvanic skin response. Psychological Bulletin, 65(5), 261–279. doi: http://dx.doi.org/10.1037/h0023204

Moseley, G.L., Gallace, A., & Spence, C. (2012). Bodily illusions in health and disease: Physiological and clinical perspectives and the concept of a cortical "body matrix." Neuroscience & Biobehavioral Reviews, 36(1), 34–46. doi: http://dx.doi.org/10.1016/j.neubiorev.2011.03.013

Moseley, G.L., Olthof, N., Venema, A., Don, S., Wijers, M., Gallace, A., & Spence, C. (2008). Psychologically induced cooling of a specific body part caused by the illusory ownership of an artificial counterpart. Proceedings of the National Academy of Sciences, 105(35), 13169–13173. doi: http://dx.doi.org/10.1073/pnas.0803768105

Price, C.J., & Thompson, E.A. (2007). Measuring dimensions of body connection: Body awareness and bodily dissociation. The Journal of Alternative and Complementary Medicine, 13(9), 945–953. doi: http://dx.doi.org/10.1089/acm.2007.0537

Saul, J.P., Albrecht, P., Berger, R.D., & Cohen, R.J. (1987). Analysis of long term heart rate variability: Methods, 1/f scaling and implications. Computers in Cardiology, 14, 419–422.

Sierra, M., & Berrios, G.E. (1998). Depersonalization: Neurobiological perspectives. Biological Psychiatry, 44(9), 898–908. doi: http://dx.doi.org/10.1016/S0006-3223(98)00015-8

Steinberg, M., Cicchetti, D., Buchanan, J., & Hall, P. (1993). Clinical assessment of dissociative symptoms and disorders: The Structured Clinical Interview for DSM-IV Dissociative Disorders (SCID-D). Dissociation: Progress in the Dissociative Disorders, 6, 3–15.

Stiglmayr, C., Schmahl, C., Bremner, J.D., Bohus, M., & Ebner-Priemer, U. (2009). Development and psychometric characteristics of the DSS-4 as a short instrument to assess dissociative experience during neuropsychological experiments. Psychopathology, 42(6), 370–374. doi: http://dx.doi.org/10.1159/000236908

Tan, G., Wang, P., & Ginsberg, J. (2013). Heart rate variability and posttraumatic stress disorder. Biofeedback, 41(3), 131–135. doi: http://dx.doi.org/10.5298/1081-5937-41.3.05

Tsakiris, M., Tajadura-Jiménez, A., & Costantini, M. (2011). Just a heartbeat away from one’s body: Interoceptive sensitivity predicts malleability of body-representations. Proceedings of the Royal Society of London B: Biological Sciences, 278(1717), 2470–2476. doi: http://dx.doi.org/10.1098/rspb.2010.2547

Weathers, F.W., Litz, B.T., Keane, T.M., Palmieri, P.A., Marx, B.P., & Schnurr, P.P. (2013). The PTSD Checklist for DSM-5 (PCL-5). Scale available from the National Center for PTSD. Retrieved from www.ptsd.va.gov

Xu, X., & Schuckers, S. (2001). Automatic detection of artifacts in heart period data. Journal of Electrocardiology, 34(4), 205–210. doi: http://dx.doi.org/10.1054/jelec.2001.28876