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# Effectiveness of intensive exposure therapy for persistent post-concussion symptoms: an aggregated single-case design approach

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## Highlights

- Explored exposure therapy for post-concussion symptoms after mild brain injury.
- Five multi-phase single-case studies (SCEDs) were conducted with 20 participants.
- Exposure therapy reduced avoidance, improved satisfaction, and eased symptom burden.
- Findings support exposure therapy's effectiveness for post-concussion symptoms.
- Results support the fear-avoidance model and exposure for this population.

## Abstract

The fear-avoidance model suggests that catastrophising and avoidance behaviours can maintain persistent post-concussion symptoms (PPCS) after mild traumatic brain injury (mTBI). Although exposure therapy has shown preliminary success in this population, its effectiveness in mTBI remains unproven. This study investigated the therapeutic effects of this therapy across different settings. Twenty participants with PPCS took part in five concurrent multiple-baseline, multi-phase single-case experimental design studies. Phases included: baseline (A), exploration (B), active exposure (C), booster (D), and follow-up (E). Participants endorsed daily visual analogue scales assessing activity avoidance, satisfaction with daily functioning, and symptom experience. Data were aggregated and analysed using multi-level modelling. Results showed that the therapy effectively reduced avoidance behaviour, increased satisfaction, and reduced symptom burden. Phase B did not differ from baseline, whereas phase C, D, and E differed from baseline for avoidance (phase C: estimate=−4.33, $p<.001$; phase D: estimate=−4.02, $p<.001$; phase E: estimate=−3.92, $p=.002$), and satisfaction. Improvements in symptom burden were seen between baseline and phases D and E. Further analyses revealed that sex, treatment setting, and history of mental health treatment moderated the effects of avoidance. No other moderation effects were found. The rigorous study design, multiple replications, and robust statistical methods provide preliminary support for the effectiveness of this innovative therapy for PPCS. Additionally, findings reinforce the relevance of the fear-avoidance model and add to the growing evidence highlighting the benefits of exposure therapy – particularly intensive exposure approaches – for mTBI.

Previous Next

## Keywords

Intensive exposure therapy; Persistent post-concussion symptoms; Mild traumatic brain injury; Multi-level modelling; Single-case experimental desig

Persistent postconcussion symptoms (PPCS), which occur frequently after mild traumatic brain injury (mTBI; Cancelliere et al., 2023; Cnossen et al., 2018), are associated with reductions in health-related quality of life (Voormolen et al., 2019), increased distress (Sheldrake et al., 2022), and limitations in daily life activities (work, social; Cancelliere et al., 2023), in addition to high societal and health-care costs (Fallesen & Campos, 2020; van der Vlegel et al., 2021). PPCS include a constellation of cognitive (i.e., memory and concentration difficulties), emotional (i.e., anxiety, irritability), and somatic (i.e.,

headaches, sensory hypersensitivity) sequelae and are associated with multidimensional interactions between different somatic, psychological, and social factors (Polinder et al., 2018; Ponsford et al., 2019).

Factors such as fear of symptom exacerbation, negative illness perceptions, and avoidance behaviours may influence maintenance of and recovery from PPCS (Anderson & Fitzgerald, 2020; Snell et al., 2023; Vermeer et al., 2025), thereby indicating the importance of psychoeducation and psychotherapeutic interventions. The fear-avoidance model of mTBI (FAM; Silverberg et al., 2018; Wijenberg et al., 2017) posits that when individuals interpret post-concussion experiences as threatening, they may engage in fear-driven responses, including avoidance and safety-seeking behaviours. These behaviours are negatively reinforced because temporarily avoiding or reducing exposure to perceived symptom triggers alleviates distress, which maintains and can intensity subjective complaints over time. Negative perceptions of symptoms, combined with avoidance, can thereby limit participation in work and social activities, creating a self-perpetuating cycle of functional impairment and symptom focus (Wijenberg et al., 2020). Evidence supporting effective treatment strategies is limited and the efficacy of interventions remains uncertain (Heslot et al., 2022; Rytter et al., 2021). Strategies that target specific psychological factors prolonging PPCS, for example exposure therapy aimed at lessening fear avoidance, may improve outcomes (Silverberg & Mikolić, 2023; Terpstra et al., 2021).

Exposure therapy, a specific application of cognitive behavioural therapy (CBT), is a well-established approach for reducing fear and avoidance behaviours (Craske et al., 2022; Knowles & Tolin, 2022; Treanor & Barry, 2017). During exposure therapy, individuals repeatedly confront avoided activities to disconfirm negative expectations, which lessens fear and avoidance (Craske et al., 2022; Knowles & Tolin, 2022). Evidence suggests that the effectiveness of the exposures is maximised when these are conducted temporally close together (Craske et al., 2012), such as in intensive exposure treatments. While one-session a week exposure therapy has showed effectiveness in reducing fear avoidance behaviours after mTBI (Hecker et al., 2024; Rioux et al., 2024; Silverberg et al., 2022), research on intensive (sessions provided over a compact time period) exposure for mTBI has, to date, only been piloted in our study (King et al., 2024). By exposing patients to the feared or avoided activities (e.g., grocery shopping) without the feared outcomes (e.g., overstimulation, fainting, accidents, etc.) occurring, improvements in avoidance behaviours, satisfaction, and symptom burden were seen (King et al., 2024).

While the pilot study demonstrated efficacy of the novel intensive exposure intervention for PPCS after mTBI (King et al., 2024) (hereafter termed therapy), further application of this therapy in a broader sample is needed. Increasing the evidence base for this therapy will lead to a better understanding of the therapy's effectiveness and generalisability and

is important for informing clinical practice, guiding treatment recommendations, and enhance understanding of PPCS. Therefore, the present study investigated the therapeutic effect of this therapy across different settings. The following hypotheses were formulated: 1) the therapy will reduce avoidance behaviours, and improve satisfaction and symptom experiences and, 2) the addition of active exposure elements in the therapy will reduce avoidance behaviours beyond the effects of providing attention to participants' problems.

# 1. Methods

## 1.1. Design

Concurrent multiple-baseline multi-phase (A-B-C-D-E) single case experimental designs (SCEDs) with randomised baselines were performed across three settings: a university site (King et al., 2024) and two rehabilitation centres in the Netherlands. Five SCEDs were performed in total (including the previous pilot SCED (King et al., 2024)), each with four participants, resulting in a combined sample of 20 participants. Across all the SCEDs the design was consistent (see Fig. S1 in Supplementary Materials). Baseline (A phase) ranged from 9 to 41 days ($M$=25.8, $SD$=7.4). The three-phase therapy period consisted of an exploration phase (B phase), an active exposure phase (C phase), and a booster phase (D phase). After the therapy, there was a follow-up phase (E phase; between 4 and 6 weeks depending on the SCED). To enhance the power of the design, the exploration phase (B phase; completing a case conceptualization) served to provide attention to participants' problems without utilising active therapy components (placebo response), thereby serving as an additional control beyond baseline. The same repeated measurements were taken throughout the SCEDs, allowing for aggregation of all the SCEDs data. The Ethical Review Committee of Psychology and Neuroscience of Maastricht University (ERCPN 250_44_03–2022; 250_44_03_2022_A2; 275_132_12_2023; 275_132_12_2023_A2) and the local ethics committees of the rehabilitation centres provided approval. The SCEDs followed the quality guidelines for SCED reporting and analyses (Manolov & Moeyaert, 2017; Tate et al., 2015, 2019).

## 1.2. Participants

Participants in the SCEDs that took place at the university were recruited via advertisements on social media. In the healthcare centres, individuals referred by healthcare professionals to undergo rehabilitation for their PPCS, were assessed for eligibility in the study. Inclusion criteria for all SCEDs were: having sustained a concussion 6–18 months prior to study inclusion; aged between 18 and 65 years; self-reporting at least 3 post-concussion symptoms as named on the Rivermead Postconcussion Symptoms Questionnaire (RPQ) which emerged after the injury and

interfered with daily life activities; fluent in Dutch; symptoms not explained by other pathologies or medical conditions; where possible stable medication regime (if applicable). In addition to the above criteria, participants in the healthcare settings also needed to meet the specific criteria of the rehabilitation healthcare centre. This typically included being motivated for treatment and having a diagnosis of PPCS made by a medical professional following a concussion. Participants were excluded if they believed their symptoms were solely due to biological causes, or if they had a psychiatric condition that needed to be addressed first. To facilitate recruitment at the healthcare centres, and to provide a representative sample of the patients seen in these settings, the criterion regarding time since concussion was extended to between 3 and 24 months prior to study inclusion. Participants were excluded from the study if they met the following criteria: traumatic brain injury with hospital admission in the past and/or a history of neurological disorder (such as epilepsy); comorbid psychiatric disorder(s) for which specialised treatment is currently received or indicated; severe co-morbidity possibly affecting the outcome (e.g., drug or alcohol addiction); history of exposure therapy/treatment for PPCS; currently receiving psychological treatment for the PPCS; premorbid dependence in daily functioning or autonomy concerns prior to the concussion (defined as: inability to perform tasks independently); currently enrolled in a personal insurance injury case/legal procedure related to the concussion; currently enrolled in another research study on PPCS treatment.

## 1.3. Intensive exposure therapy

The therapy protocol drew on insights into the working mechanisms of exposure treatments (Craske et al., 2014; Craske et al., 2022; Rijkeboer & van den Hout, 2014) and existing knowledge of exposure therapy across different conditions (Hendriks et al., 2018; King et al., 2024; Leeuw et al., 2008). The exploration phase (B) included two 60-min sessions, completed over one to two weeks. Sessions focused on exploring and attending to the participants' problems/symptoms through idiosyncratic case conceptualization (Craske et al., 2022). During the active exposure phase (C), 90-min individual sessions were provided intensively over five consecutive days. Sessions consisted of one psychoeducation session, eight (SCEDs at healthcare setting) or nine/ten (SCEDs at university setting) exposure sessions, one preparatory session for a final session involving significant others, and one session with those significant other(s) present. During the psychoeducation session, participants were introduced to the fear-avoidance model (Silverberg et al., 2018; Wijenberg et al., 2017) and the current understanding of PPCS, basic education about the brain, and an overview of the intensive exposure therapy, emphasising that exposure is not harmful to the brain. In the exposure sessions, behavioural experiments were set-up, performed, and evaluated, with rotating therapists, targeting activities which participants indicated were bothersome or which

they avoided. Experiments focused on testing the negative expectations (i.e., fearful predictions) participants held related to the bothersome or avoided activities. For example, if a participant indicated that they would have word finding problems (negative expectation) within 15 min of mental activity with distraction (avoided activity), then this was tested during the exposure session by having the participant do mental activity for 15 min with distractions and determine if the negative expectation occurred. The final session was conducted with the participants' significant other(s) to stimulate generalisation of the therapeutic gains to the home situation and allow participants to convey their learning experiences from the past days. To support indirect exposure, participants also joined in additional activities outside of sessions (such as walking, fitness, etc.). During the active exposure phase (C), participants were encouraged to stay in a hotel, to remove participants from their daily routine and environment, limiting opportunities for avoidance. In the first SCED at the university, the hotel was paid for whereas in the remaining SCEDs participants covered their own costs. Moreover, in the SCEDs in the rehabilitation centres, not all participants stayed in the hotel; some returned home after each treatment day. In the booster phase (D), home exercises were discussed stimulating generalisation to the participants' environment and consolidating treatment effects. This phase included two 60-min sessions once a week starting one week after the end of the exposure phase. An overview of the key therapy components is provided in Table 1.

Table 1. Key therapy components.

| Study Phase | Number of Sessions | Objective(s) | Activities | Duration | Participants | Expected Outcomes |
|---|---|---|---|---|---|---|
| B | Two | Explore and provide attention to participants' problems and symptoms | Complete an idiosyncratic case conceptualization | 60-min | Individual participants with therapist | Participants feel listened to and heard; Prepare personalized treatment plan |
| C | One | Introduce participants to the current understanding of PPCS and provide an overview of the | Discuss the fear-avoidance model and current understanding of PPCS, basic education about the brain, and | 90-min | All participants and therapists | Participants gain an understanding of PPCS and current theoretical underpinnings |

| Study Phase | Number of Sessions | Objective(s) | Activities | Duration | Participants | Expected Outcomes |
|---|---|---|---|---|---|---|
| | | exposure therapy | provide an outline of the exposure therapy | | | and have an overview of the exposure therapy |
| C | Eight/nine[a] | Test negative expectations participants had related to the activities they avoided or felt were bothersome | Discuss and test the negative expectations participants held related to the avoided activities and evaluate if the negative expectation occurred; individualized per participant; Example: word finding problems (negative expectation) after 15 min of mental activity with distraction (avoided activity) | 90-min sessions | Individual participant and therapist | Negative expectations did not occur after completing the avoided activity; belief in negative expectations lessens |

| Study Phase | Number of Sessions | Objective(s) | Activities | Duration | Participants | Expected Outcomes |
|---|---|---|---|---|---|---|
| C | One | Plan and prepare participants for the session with their significant others | Discuss what participants had learnt during the exposure sessions, and plan what they would do at home to keep improving; discuss how they were going to convey this to their significant others | 90-min session | Individual participant and therapist | Participants think about and consolidate what they learnt and how they plan to implement this into their home environment |
| C | One | Session with significant others to convey what participants learnt and what they plan to do in their home environment to continue therapy gains | Discuss with their significant others what they had learnt and their plans for their home environment (i.e., what their significant others should or should not do to help) | 90-min session | Individual participant, therapist, and significant others | Provide participants the opportunity to tell their significant others what they had learnt, and to allow for greater success and understanding with their generalization plans |
| D | Two | Determine how participants are progressing at home and provide guidance on consolidating treatment effects | Discuss how participants are progressing at home, and provide home exercises | 60-min sessions | Individual participant and therapist | Stimulate generalization to the participants' environment and consolidate treatment effects |

*Note.* Phase B – exploration phase, Phase C – active exposure phase, D – booster phase.

a

dependent on the study.

## 1.4. Setting

The SCEDs were performed across different settings, namely the university (two SCEDs), and two healthcare settings in the Netherlands, rehabilitation centres Heliomare (two SCEDs) and Klimmendaal (one SCED). At each setting, psychologists with experience in CBT performed the sessions. The clinical psychologist (MR) who developed the protocol provided training to the therapists on the protocol and daily supervision during the treatment phase (B, C, D), except for the second SCED in Heliomare, where MF trained the new therapists. Therapists rotated between participants to lessen interpersonal dependency and allow greater variation of context (Krampe & Ehrenreich, 2012; Van Minnen et al., 2018) to be achieved.

## 1.5. Procedure

All participants completed the intervention simultaneously within each SCED study. Additional measurements were collected during the studies, however the present study reports on the repeated measurements only. The procedure details for each setting are provided below.

## 1.6. University setting

Participants that were interested in the research, contacted the researchers who then checked their eligibility based on the in/exclusion criteria. Those meeting the criteria did online meetings with a neurologist (JvdN), and a clinical psychologist (MR) and neuropsychologist (CvH) to finalise eligibility. After informed consent was provided, baseline length was randomly determined (using Microsoft Excel) and participants were directed via email to complete the demographic questionnaire (T0) and repeated measurements in the online testing environment (m-path (Mestdagh et al., 2023) and Qualtrics. Participants in the first SCED (King et al., 2024) completed the repeated measurements daily in the baseline and intervention phases, and weekly in the follow-up phase. In the second SCED, repeated measures were collected daily throughout the SCED.

## 1.7. Healthcare settings

A clinical neuropsychologist (MF; NF) and rehabilitation physician checked participants referred for rehabilitation treatment at either healthcare setting for eligibility to

participate in the study. Participants provided consent for their details to be provided to the researchers. After contact with the researcher, participants gave informed consent and were instructed to complete the demographic questionnaire (T0) and the repeated measurements in the online testing environment. Participants in all SCEDs completed the repeated measures daily throughout the study period.

## 1.8. Measurements

Participants rated statements using a sliding bar visual analogue scale (VAS) via the online environment to assess the intervention effects. To assess the degree of avoidance of feared activities (hereafter referred to as avoidance), the statement "I have avoided certain activities today because of my symptoms" was measured from 0 (strongly disagree) to 10 (strongly agree). Lower scores indicated less avoidance (in the desired treatment direction). The statement "how satisfied are you with your daily functioning?" endorsed from 0 (not at all) to 10 (very satisfied), assessed participants satisfaction with their daily functioning (hereby referred to as satisfaction). Higher scores indicated higher satisfaction. Symptom experience (how patients perceive, evaluate, and function with symptoms(Dodd et al., 2001)) was assessed with the statement "today my symptoms were …" from 0 (very bad) to 10 (very good/not present). Higher scores indicated less symptom burden.

At the beginning of the SCEDs, participants completed a self-reported questionnaire containing demographic questions including age, sex, history of mental health treatment (i.e., psychological, psychiatric, or pharmacological interventions for a mental health condition such as anxiety, depression, etc.), questions on injury-related variables, and additional measures on catastrophising (Postconcussion Symptoms Catastrophising Scale: PCS-CS; Wijenberg et al., 2017), fear-avoidance (Fear of Mental Activity: FMA; Wijenberg et al., 2017), and depression and anxiety (Hospital Anxiety and Depression Scale: HADS; Zigmond & Snaith, 1983).

## 1.9. Statistical analysis

Data were analysed using R (v 4.4.3) (R Core Team, 2021). Time-series graphs were plotted per participant across the variables of avoidance, satisfaction, and symptom experience using GraphPad Prism 10 (see Figs. S2–4 in Supplementary Materials). To visualise the distribution characteristics of the variables avoidance, satisfaction, and symptom experience within and across phases, violin plots were generated for each phase using the raw data across participants (Tanious & Manolov, 2022, 2025). As missing data often occurs within SCED research due to the repeated nature of the design and may decrease the generalisability and validity of results (Aydin, 2024b), the percentage of missing data per participant was assessed (see Supplementary Table S1).

While there was no participant attrition, rates of missingness were moderate (<30%) to high (<50%) for some participants, therefore multiple imputation was used to decrease Type 1 error (Aydin, 2024a; Peng & Chen, 2018, 2021). Multiple imputation avoids potential bias and retains the data structure of the study and collected data and while it is a novel approach in the SCED context it has shown to be successful with SCED data (De et al., 2020; Peng & Chen, 2018). Multiple imputation was performed with the 'mice' package (v 3.17.0) (van Buuren & Groothuis-Oudshoorn, 2011), using predictive mean matching ('pmm') across all variables with missing data. To ensure good convergence of the imputation, diagnostic plots (using 'ggplot2', v 3.5.2; Wickham, 2016 and 'mice') and comparison between the original dataset and the imputed datasets ($n$=5) were analysed. All analyses were performed on all the imputed datasets and then statistics were pooled (using 'mitools' v 2.4; Lumley, 2019). Standard errors were pooled using Rubin's rules (Rubin, 1987).

Non-overlap of all pairs (NAP) was used as the effect measure between each adjacent phase for each participant (Parker & Vannest, 2009), and a combined NAP was applied as the mean of all the adjacent phase NAP. NAP results for the original dataset are in Supplementary Table S2. NAP is applicable to variable data (Parker et al., 2011) and is not sensitive to the number of measurements (Pustejovsky, 2019) which is beneficial in the current study which has a small number of measurements in phase C (active exposure). The following ranges were used to interpret NAP: 0 to .65 weak effects, .66 to .92 medium effects, and .93 to 1 large effects (Parker & Vannest, 2009). NAP was calculated using the SingleCaseES package in R (R Core Team, 2021), v .7.3 (Pustejovsky et al., 2024).

Autocorrelation is frequently observed in SCED data and can lead to an increased likelihood of Type I or II errors (Baek et al., 2023). Autocorrelation was analysed using the acf function in R (R Core Team, 2021), with a lag-1 coefficient of .5 or higher considered as high (Archer et al., 2019). Some autocorrelation is present in the data (see Supplementary Table S3).

Multi-level modelling (MLM) was used to estimate the average intervention effect aggregated across the 20 cases from the 5 studies, using a three-level model to take into account the hierarchical nature of the data (daily measures of the same participant nested into cases nested into studies) (Moeyaert et al., 2020; Van den Noortgate and Onghena, 2007). As autocorrelation was present in the data, a first-level autoregressive structure (AR1) was specified in the model. To assess the addition of the active exposure elements (C) over and above attending to participants problems (exploration, B), phase contrasts were performed. To control for inflated Type I errors when using multiple testing on the phase contrasts (Tanious et al., 2019), the false discovery rate (FDR) adjusted method (Benjamini & Hochberg, 2000) was used to correct the observed p-values. The potential moderation effects of age, sex, setting (university, healthcare

centres), time since injury, and history of mental health treatment on the intervention effect were also analysed in a combined model with phase and time. The 'lme4'(v 1.1–37; Bates et al., 2015), 'lmerTest' (v 3.1–30; Kuznetsova et al., 2017), 'nlme' (v 3.1–168; Pinheiro et al., 2025), 'emmeans' (v 1.11.0; Lenth, 2025), and 'mutoss' (v .1–13; Blanchard et al., 2023) packages were used in R (R Core Team, 2021) to compute the three-level models. Between-case standardised mean difference (BC-SMD) was utilised as a measure of effect for the aggregated data of the multi-level models (Hedges et al., 2012; Hedges et al., 2010). While there is no universal consensus on the interpretation of BC-SMD, guidelines suggest that .01–.20 can be interpreted as a small effect, .21–.59 a moderate effect, and .60 and above a large effect (Valentine et al., 2016).

Sensitivity analysis was conducted, comparing the results on the original dataset (with missing data) to the results from the pooled imputed dataset, to determine convergence (see Supplementary materials Tables S2, S4-S6 for original results). For each analytic method (NPA, MLM, BC-SMD), the consistency across estimates, confidence intervals, standard errors, and significance levels were examined.

## 2. Results

### 2.1. Participant characteristics

Participant characteristics are presented in Table 2. Violin plots in Fig. 1, Fig. 2, Fig. 3, show the distributions of raw data across phases for all participants. The plots show the mean per phase for each SCED study (1 and 2 at university setting, 3, 4 and 5 at healthcare settings). In Fig. 1, Fig. 2, Fig. 3, the distribution of scores shifted in the desired treatment direction during the active exposure phase (C). Time-series graphs displaying the raw data across time per participant per variable are provided in the Supplementary Materials Figs. S1–S3.

Table 2. Participant characteristics.

| **Variable** | **(*n*=20)** |
|---|---|
| Age, mean (SD) [range] | 34.7 (13.5) [19–59] |
| Sex, n (%) | |
| Male | 6 (30) |
| Female | 14 (70) |
| Time since injury (months), mean (SD) [range] | 10.4 (5.7) [3–24] |
| Cause of Injury | |

| Variable | (*n*=20) |
|---|---|
| Fall | 3 (15) |
| Traffic | 5 (25) |
| Sport | 4 (20) |
| Struck by object | 5 (25) |
| Accident | 2 (10) |
| Other | 1 (5) |
| Loss of consciousness, n (%) | 11 (55) |
| Post traumatic amnesia, n (%) | 9 (45) |
| Catastrophising, mean (SD) [range] | 23.7 (6.8) [11–39] |
| Activity avoidance, mean (SD) [range] | 18.4 (4.5) [9–26] |
| Somatic focus, mean (SD) [range] | 11.6 (2.3) [7–16] |
| Anxiety, mean (SD) [range] | 10.4 (3.5) [3–16] |
| Depression, mean (SD) [range] | 9.3 (3.8) [1–16] |
| Education High, yes n (%) | 10 (50) |
| History of mental health treatment, yes n (%) | 7 (35) |
| Job Prior Injury | |
| Yes, n (%) | 20 (100) |
| Hours, mean (SD) [range] | 30.9 (14.0) [0–60] |
| Job After Injury | |
| Yes, n (%) | 12 (60) |
| Hours, mean (SD) [range] | 7.0 (10.4) [0–30] |
| Hotel stay during therapy, Yes, n (%) | 18 (90%) |

*Note.* Catastrophising measured by the PCS-CS, activity avoidance and somatic focus measured by the FMA, anxiety and depression measured by the HADS.

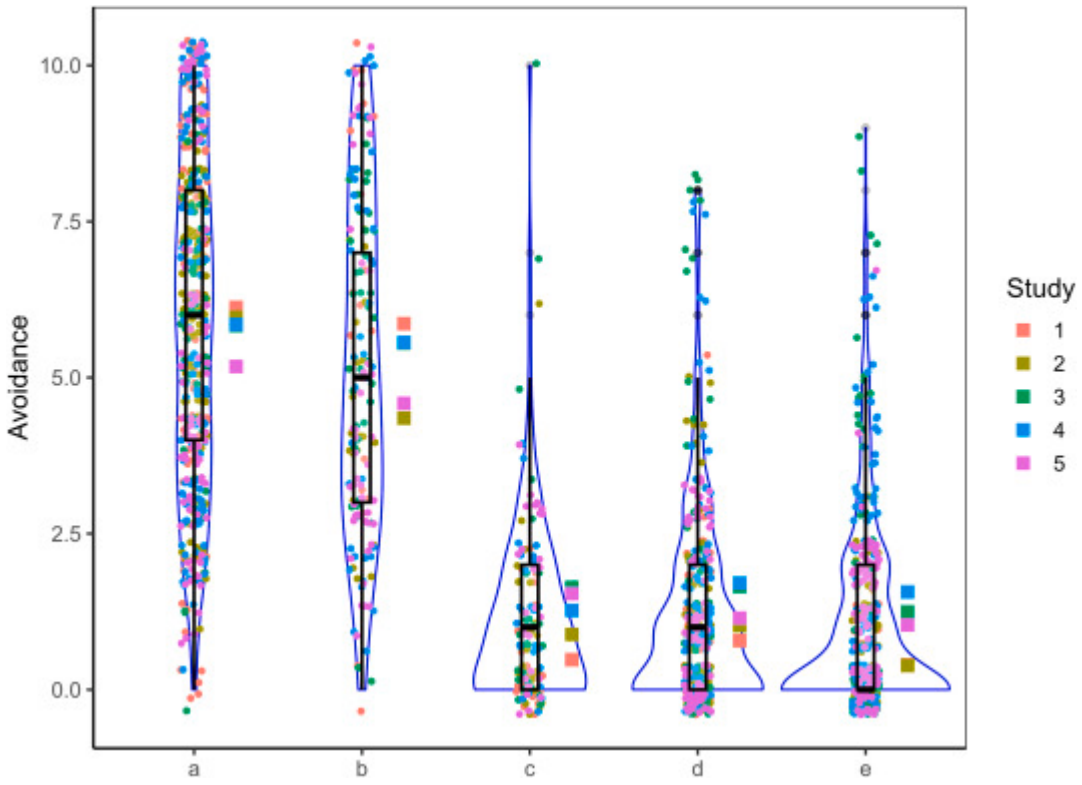


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Fig. 1. Violin plot of raw data for *avoidance* across participants and phases.
*Note.* dots: raw avoidance scores per participant, squares: mean avoidance scores per study. Colors denote the studies and participants belonging to each study. a – baseline phase, b – case conceptualization phase, c – active exposure phase, d – booster phase, e – follow-up phase. Study 1 and 2 are from the UM setting, study 3, 4 and 5 are from the rehabilitation settings. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

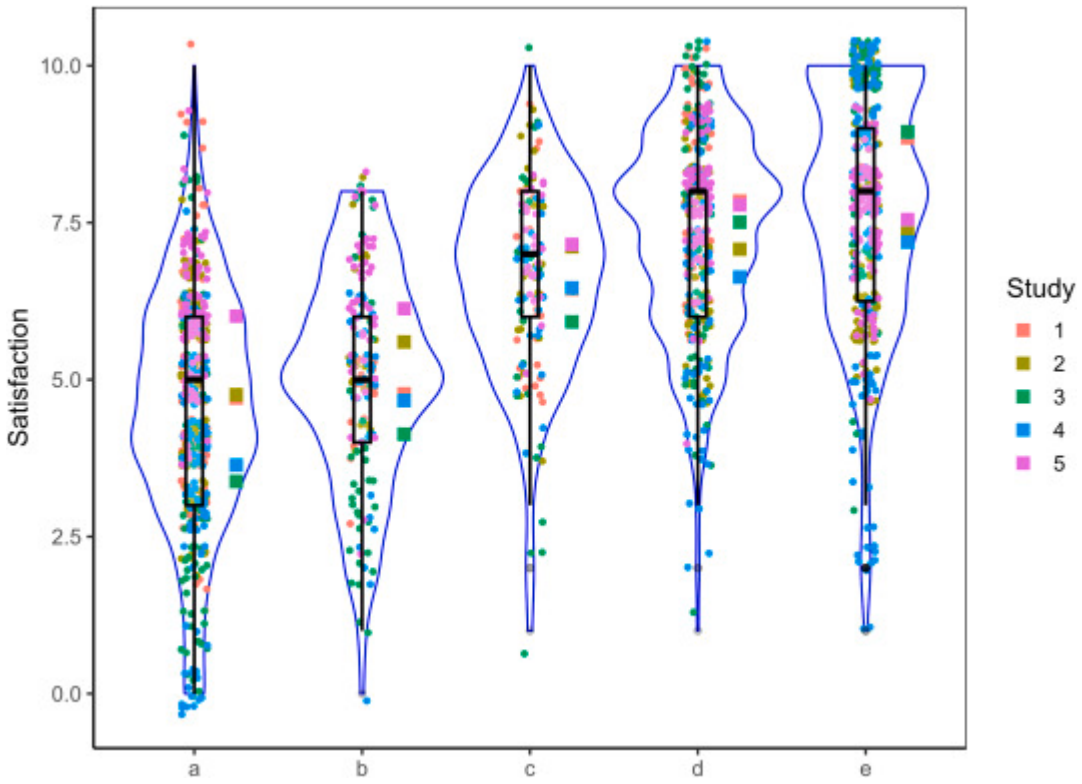


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Fig. 2. Violin plot of raw data for *satisfaction* across participants and phases.
*Note.* dots: raw satisfaction scores per participant, squares: mean satisfaction scores per study. Colors denote the studies and participants belonging to each study. a – baseline phase, b – case conceptualization phase, c – active exposure phase, d – booster phase, e – follow-up phase. Study 1 and 2 are from the UM setting, study 3, 4 and 5 are from the rehabilitation settings. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

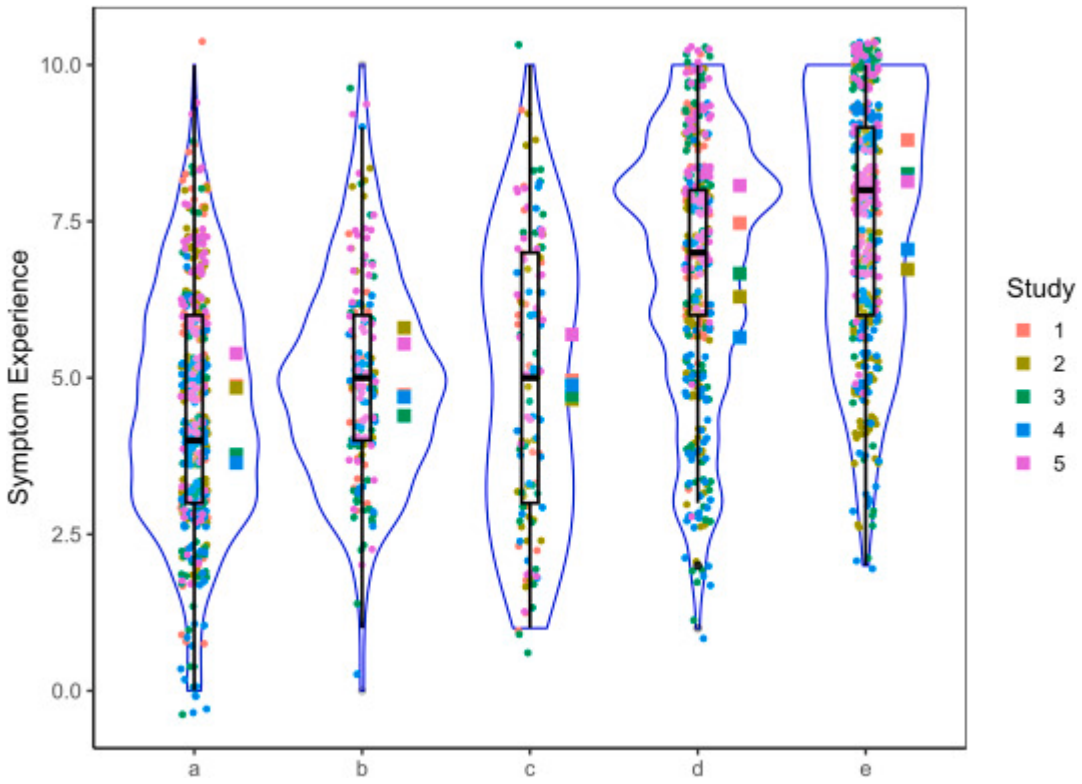


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Fig. 3. Violin plot of raw data for *symptom experience* across participants and phases. *Note.* dots: raw symptom experience scores per participant, squares: mean symptom experience scores per study. Colors denote the studies and participants belonging to each study. a – baseline phase, b – case conceptualization phase, c – active exposure phase, d – booster phase, e – follow-up phase. Study 1 and 2 are from the UM setting, study 3, 4 and 5 are from the rehabilitation settings. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

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The variables of avoidance, satisfaction, and symptom experience contain missing data (ranging from 0 to 45% across participants). Missing data is most likely missing at random (MAR) as entire days of data are missing across all 3 variables (avoidance, satisfaction, symptom experience), suggesting that participants missed the data entry for the whole day rather than for individual items. These missing days occur at random across phases. Overall, 8.54% of the data for these variables is missing across the entire sample. Supplementary Table S1 shows the percentage of missing data per variable per participant. While the overall rate of missing data is within acceptable estimates (Peng & Chen, 2021), the range of missing data across participants is variable and high. Therefore, multiple imputations were performed on the data. The results presented are based on the pooled estimates from the imputed datasets.

## 2.2. Non-overlap of all pairs (NAP)

Table 3 presents the non-overlap of all pairs (NAP) for all participants for each adjacent phase and combined. For avoidance, satisfaction, and symptom experience, a weak to medium effect (ranging between .23 and .92) was shown between baseline (A) and exploration phase (B) across all participants. Between exploration (B) and active exposure (C) the effect for avoidance ranged from medium to strong (between .79 and 1.00) for all participants (except participant 17 which showed a weak effect of .65). NAP ranged from weak to medium effect (ranging between .32 and .89) for avoidance between phases C (active exposure) and D (booster), and between phase D (booster) and E (follow-up; except for participant 17 which showed a strong effect of .98). NAP were variable (weak to strong) for satisfaction and symptom experience between the phases B and C, C and D, and D and E.

Table 3. NAP results for each avoidance, satisfaction, and symptom experience per participant.

| PPN | Phase 1 | Phase 2 | Avoidance | Satisfaction | Symptom Experience |
|---|---|---|---|---|---|
| | | | **Estimate (SE) [95% CI]** | | |
| 1 | A | B | .37 (.11) [.15, .58] | .42 (.10) [.22, .62] | .37 (.09) [.20, .55] |
| | B | C | **.98** (.04) [.91, 1.05] | **.96** (.07) [.82, 1.09] | .72 (.15) [.43, 1.02] |
| | C | D | .50 (.12) [.26, .73] | .61 (.10) [.41, .82] | .77 (.11) [.56, .98] |
| | D | E | .63 (.11) [.42, .85] | .47 (.12) [.22, .71] | .51 (.12) [.27, .75] |
| | Combined | | .60 (.28) [.05, 1.15] | .61 (.44) [-.25, 1.48] | .59 (.53) [-.44, 1.63] |
| 2 | A | B | .56 (.12) [.31, .80] | .81 (.07) [.68, .94] | .68 (.14) [.41, .96] |
| | B | C | **.99** (.02) [.95, 1.03] | .63 (.12) [.38, .87] | .23 (.14) [-.04, .50] |
| | C | D | .22 (.11) [.00, .44] | .86 (.08) [.71, 1.02] | .86 (.09) [.68, 1.04] |
| | D | E | .83 (.07) [.70, .96] | .91 (.05) [.80, 1.02] | **.93** (.05) [.83, 1.03] |
| | Combined | | .64 (.18) [.29, .99] | .80 (.38) [.06, 1.54] | .68 (.50) [-.30, 1.65] |
| 3 | A | B | .73 (.10) [.53, .93] | .76 (.12) [.52, 1.00] | .69 (.12) [.46, .92] |
| | B | C | **.99** (.02) [.95, 1.03] | .90 (.12) [.67, 1.14] | .33 (.15) [.04, .62] |
| | C | D | .41 (.10) [.22, .60] | .92 (.05) [.82, 1.02] | **.98** (.02) [.94, 1.02] |
| | D | E | .48 (.12) [.24, .72] | .84 (.06) [.72, .95] | .78 (.10) [.58, .97] |
| | Combined | | .65 (.17) [.31, .99] | .85 (.38) [.10, 1.61] | .69 (.48) [-.24, 1.63] |
| 4 | A | B | .57 (.13) [.30, .83] | .46 (.10) [.26, .66] | .23 (.09) [.06, .40] |

| PPN | Phase 1 | Phase 2 | Avoidance | Satisfaction | Symptom Experience |
|---|---|---|---|---|---|
| | | | Estimate (SE) [95% CI] | | |
| | B | C | .84 (.11) [.61, 1.06] | .85 (.09) [.67, 1.03] | **.97** (.04) [.90, 1.04] |
| | C | D | .51 (.10) [.32, .70] | **.99** (.02) [.94, 1.04] | .78 (.10) [.59, .97] |
| | D | E | .57 (.06) [.45, .69] | **.93** (.06) [.83, 1.04] | **.93** (.06) [.81, 1.05] |
| | Combined | | .62 (.21) [.21, 1.03] | .81 (.33) [.15, 1.46] | .73 (.33) [.07, 1.38] |
| 5 | A | B | .92 (.05) [.83, 1.01] | .62 (.09) [.45, .79] | .53 (.10) [.33, .72] |
| | B | C | **1.00** (.02) [.97, 1.03] | **.94** (.07) [.81, 1.07] | .27 (.15) [-.03, .57] |
| | C | D | .54 (.16) [.23, .85] | .46 (.14) [.18, .74] | .87 (.09) [.69, 1.05] |
| | D | E | .75 (.07) [.62, .88] | .34 (.07) [.21, .48] | .33 (.08) [.18, .48] |
| | Combined | | **.82** (.20) [.43, 1.21] | .59 (.43) [-.26, 1.43] | .50 (.48) [-.44, 1.44] |
| 6 | A | B | .83 (.15) [.54, 1.12] | .74 (.12) [.51, .97] | .84 (.10) [.64, 1.03] |
| | B | C | .86 (.13) [.61, 1.11] | .83 (.15) [.53, 1.13] | .01 (.04) [-.07, .09] |
| | C | D | .25 (.14) [-.02, .51] | .42 (.14) [.16, .69] | .88 (.06) [.76, .99] |
| | D | E | .83 (.06) [.71, .94] | .75 (.06) [.62, .87] | .80 (.06) [.68, .92] |
| | Combined | | .71 (.20) [.31, 1.11] | .68 (.52) [-.34, 1.71] | .63 (.30) [.05, 1.21] |
| 7 | A | B | .75 (.17) [.41, 1.09] | .86 (.06) [.74, .98] | .90 (.07) [.76, 1.03] |
| | B | C | **1.00** (.03) [.94, 1.06] | .77 (.15) [.47, 1.06] | .45 (.20) [.06, .83] |
| | C | D | .47 (.11) [.26, .69] | .62 (.12) [.38, .85] | .66 (.15) [.37, .95] |
| | D | E | .63 (.06) [.51, .75] | .84 (.06) [.73, .95] | .81 (.06) [.69, .93] |
| | Combined | | .71 (.22) [.29, 1.14] | .77 (.47) [-.15, 1.69] | .70 (.59) [-.45, 1.86] |
| 8 | A | B | .57 (13) [.31, .84] | .68 (.12) [.44, .92] | .64 (.12) [.39, .88] |
| | B | C | **.99** (.03) [.93, 1.05] | .87 (.11) [.66, 1.09] | .39 (.18) [.05, .74] |
| | C | D | .53 (.08) [.37, .70] | .41 (.12) [.17, .66] | .76 (.11) [.54, .98] |
| | D | E | .52 (.03) [.46, .58] | .44 (.08) [.29, .60] | .46 (.08) [.30, .62] |
| | Combined | | .64 (.15) [.35, .94] | .60 (.49) [-.37, 1.57] | .56 (.57) [-.56, 1.69] |
| 9 | A | B | .51 (.11) [.29, .72] | .57 (.11) [.35, .79] | .57 (.11) [.36, .78] |
| | B | C | .79 (.14) [.50, 1.07] | .85 (.08) [.68, 1.01] | .55 (.15) [.25, .85] |
| | C | D | .73 (.12) [.50, .96] | .70 (.12) [.46, .94] | .77 (.12) [.53, 1.01] |

| PPN | Phase 1 | Phase 2 | Avoidance | Satisfaction | Symptom Experience |
|---|---|---|---|---|---|
| | | | **Estimate (SE) [95% CI]** | | |
| | D | E | .65 (.06) [.53, .76] | .72 (.07) [.58, .86] | .57 (.08) [.42, .73] |
| | Combined | | .67 (.22) [.23, 1.11] | .71 (.45) [-.17, 1.58] | .62 (.53) [-.42, 1.65] |
| 10 | A | B | .63 (.13) [.37, .89] | .66 (.11) [.44, .88] | .73 (.10) [.54, .92] |
| | B | C | .81 (.14) [.54, 1.08] | .77 (.15) [.48, 1.07] | .60 (.18) [.25, .95] |
| | C | D | .23 (.11) [.02, .45] | .65 (.13) [.39, .91] | .46 (.16) [.15, .77] |
| | D | E | .51 (.09) [.34, .67] | .76 (.07) [.62, .90] | .65 (.08) [.50, .81] |
| | Combined | | .52 (.25) [.04, 1.01] | .71 (.54) [-.35, 1.77] | .61 (.60) [-.57, 1.79] |
| 11 | A | B | .59 (.11) [.38, .81] | .58 (.11) [.38, .79] | .44 (.11) [.23, .65] |
| | B | C | .87 (.12) [.63. 1.11] | .69 (.14) [.40, .97] | .45 (.15) [.16, .74] |
| | C | D | .83 (.09) [.65, 1.01] | .89 (.06) [.77, 1.01] | **.94** (.05) [.84, 1.03] |
| | D | E | .62 (.05) [.52, .72] | .83 (.05) [.73, .94] | .86 (.05) [.76, .96] |
| | Combined | | .73 (.19) [.35, 1.11] | .75 (.44) [-.11, 1.61] | .67 (.43) [-.18, 1.52] |
| 12 | A | B | .67 (.12) [.43, .91] | .45 (.12) [.22, .69] | .56 (.13) [.30, .82] |
| | B | C | **.97** (.09) [.79, 1.15] | .83 (.11) [.61, 1.05] | .56 (.17) [.23, .88] |
| | C | D | .27 (.11) [.05, .49] | .67 (.13) [.42, .92] | .49 (.13) [.24, .75] |
| | D | E | .54 (.08) [.38, .70] | .50 (.08) [.34, .66] | .62 (.08) [.46, .78] |
| | Combined | | .52 (.21) [.10, .94] | .62 (.50) [-.36, 1.59] | .56 (.59) [-.59, 1.70] |
| 13 | A | B | .55 (.09) [.37, .74] | .69 (.09) [.51, .86] | .73 (.09) [.54, .91] |
| | B | C | **1.00** (.01) [.98, 1.02] | **1.00** (.01) [.98, 1.02] | .74 (.13) [.48, 1.00] |
| | C | D | .67 (.12) [.43, .91] | .81 (.09) [.63, 1.00] | .79 (.09) [.61, .97] |
| | D | E | .64 (.05) [.54, .75] | .90 (.04) [.81, .99] | .86 (.05) [.76, .96] |
| | Combined | | .72 (.17) [.40, 1.04] | .85 (.31) [.25, 1.45] | .78 (.43) [-.06, 1.62] |
| 14 | A | B | .80 (.06) [.68, .92] | .76 (.07) [.62, .89] | .74 (.07) [.60, .89] |
| | B | C | .86 (.09) [.69, 1.04] | .66 (.16) [.34, .97] | .17 (.13) [-.08, .42] |
| | C | D | .45 (.13) [.20, .71] | .51 (.14) [.24, .78] | .75 (.11) [.53, .97] |
| | D | E | .36 (.07) [.23, .49] | .45 (.08) [.30, .61] | .65 (.08) [.50, .81] |
| | Combined | | .62 (.18) [.26, .98] | .59 (.53) [-.44, 1.63] | .58 (.45) [-.30, 1.46] |

| PPN | Phase 1 | Phase 2 | Avoidance | Satisfaction | Symptom Experience |
|---|---|---|---|---|---|
| | | | Estimate (SE) [95% CI] | | |
| 15 | A | B | .46 (.09) [.28, .64] | .82 (.06) [.70, .94] | .76 (.07) [.62, .90] |
| | B | C | **1.00** (.01) [.98, 1.02] | **.96** (.04) [.89, 1.04] | .68 (.16) [.37, .99] |
| | C | D | .47 (.11) [.24, .69] | .69 (.09) [.52, .85] | .56 (.12) [.32, .80] |
| | D | E | .63 (.07) [.48, .77] | .81 (.06) [.70, .92] | .79 (.06) [.67, .91] |
| | Combined | | .64 (.17) [.31, .96] | .82 (.28) [.26, 1.37] | .70 (.49) [-.27, 1.66] |
| 16 | A | B | .44 (.12) [.21, .66] | .64 (.10) [.45, .84] | .58 (.10) [.38, .79] |
| | B | C | .90 (.08) [.75, 1.04] | .68 (.13) [.42, .93] | .42 (.14) [.15, .68] |
| | C | D | .19 (.09) [.02, .36] | .34 (.12) [.10, .58] | .54 (.12) [.30, .79] |
| | D | E | .55 (.09) [.39, .72] | .63 (.07) [.48, .78] | .67 (.08) [.52, .82] |
| | Combined | | .50 (.19) [.12, .88] | .57 (.49) [-.38, 1.53] | .55 (.50) [-.43, 1.54] |
| 17 | A | B | .86 (.06) [.73, .98] | .86 (.05) [.77, .96] | .77 (.07) [.63, .91] |
| | B | C | .65 (.09) [.46, .84] | .57 (.09) [.39, .75] | .65 (.09) [.46, .84] |
| | C | D | .45 (.09) [.28, .62] | **.93** (.07) [.78, 1.07] | **.93** (.07) [.78, 1.07] |
| | D | E | **.98** (.02) [.93, 1.02] | .50 (.02) [.46, .54] | .50 (.02) [.46, .54] |
| | Combined | | .74 (.14) [.45, 1.02] | .72 (.29) [.15, 1.28] | .71 (.32) [.09, 1.33] |
| 18 | A | B | .71 (.09) [.54, .88] | .65 (.10) [.46, .85] | .66 (.09) [.48, .85] |
| | B | C | .79 (.14) [.51, 1.07] | .71 (.12) [.49, .94] | .50 (.14) [.22, .78] |
| | C | D | .52 (.12) [.29, .76] | .58 (.10) [.39, .78] | .80 (.08) [.63, .96] |
| | D | E | .42 (.07) [.28, .56] | .44 (.08) [.28, .60] | .44 (.08) [.28, .60] |
| | Combined | | .61 (.22) [.18, 1.04] | .60 (.44) [-.27, 1.47] | .60 (.47) [-.31, 1.51] |
| 19 | A | B | .69 (.09) [.52, .87] | .37 (.10) [.18, .56] | .34 (.09) [.16, .52] |
| | B | C | **1.00** (.01) [.98, 1.02] | .84 (.10) [.64, 1.05] | .55 (.15) [.25, .84] |
| | C | D | .32 (.12) [.09, .54] | .60 (.14) [.32, .88] | .84 (.11) [.63, 1.05] |
| | D | E | .48 (.07) [.35, .61] | .45 (.08) [.30, .61] | .47 (.08) [.31, .63] |
| | Combined | | .65 (.17) [.32, .98] | .57 (.47) [-.36, 1.50] | .55 (.48) [-.40, 1.50] |
| 20 | A | B | .55 (.10) [.35, .75] | .57 (.11) [.36, .78] | .44 (.10) [.24, .64] |
| | B | C | **.96** (.04) [.88, 1.05] | .78 (.11) [.56, 1.01] | .41 (.18) [.05, .77] |

| PPN | Phase 1 | Phase 2 | Avoidance | Satisfaction | Symptom Experience |
|---|---|---|---|---|---|
| | | | **Estimate (SE) [95% CI]** | | |
| | C | D | .89 (.08) [.73, 1.05] | .80 (.09) [.62, .99] | **.98** (.02) [.93, 1.02] |
| | D | E | .53 (.04) [.45, .61] | .38 (.08) [.23, .53] | .64 (.07) [.50, .78] |
| | Combined | | .74 (.14) [.46, 1.02] | .63 (.44) [-.24, 1.51] | .62 (.50) [-.36, 1.59] |

*Note.* Phases: A=baseline, B=exploration, C=active exposure, D=booster, E=follow-up. **Strong effect** is indicated by a value between .93 and 1.00, medium effect is .66–.92, and a value less than .66 indicates a weak effect.

## 2.3. Multi-level models

To assess the effect of the therapy across all participants while taking the different studies into account, hierarchical multi-level models were analysed. As there was autocorrelation in the data across the variables (see Supplementary Material Table S3), an autocorrelation (AR1) structure was added to the model. Table 4 shows the regression estimates and between-case standardised mean difference (BC-SMD) for each of the variables. Across all variables, the intercept (baseline phase) was significantly different from 0 ($p$<.001) while phase B (exploration) was not significantly different from baseline. In contrast, phase C (active exposure), phase D (booster), and phase E (follow-up) showed significant changes compared to baseline. Such that, avoidance decreased (phase C: estimate=−4.33, $p$<.001; phase D: estimate=−4.02, $p$<.001; phase E: estimate=−3.92, $p$=.002), and satisfaction increased. Symptom experience did not show significant changes between any of the phases and baseline. Time was significant for satisfaction and symptom experience but not avoidance. Table 5 reports the contrasts between the phases. Adding active exposure elements (C) significantly decreased avoidance (estimate=−3.91, $p$=.001), and increased satisfaction (estimate=1.19, $p$=.02) compared to the prior exploration phase (B) which attended to participants problems. Symptom experience significantly improved from phase C to D (from active exposure to booster, estimate=1.22, $p$=.04). All effects were maintained during the follow-up period (E). Table 6 shows the moderation results for variables age, sex, time since injury, setting (2=Heliomare, 3=Klimmendaal), history of mental health treatment. Females scored significantly lower than males on avoidance at baseline but significantly higher in phases C (active exposure), D (booster), and E (follow-up). Participants at Heliomare (setting 2) had significantly higher avoidance scores than participants at the university setting (setting 1) in phases C (active exposure), D (booster), and E (follow-up). Those with a history of mental health treatment scored significantly higher on avoidance at phase E (follow-up) than those without a history of mental health treatment. No other significant

moderation results were found for avoidance, satisfaction, or symptom experience. Supplementary Tables S4–S6 show the original dataset regression analysis results.

Table 4. Regression estimates.

| | Estimate | Standard Error | T-value | p-value | BC-SMD (SE) [95% CI] |
|---|---|---|---|---|---|
| **Avoidance** | | | | | |
| Intercept | 6.05 | .27 | 22.20 | .000 | – |
| Phase B | −.41 | .26 | −1.56 | .19 | −.16 (.10) [-.35; .04] |
| Phase C | −4.33 | .33 | −13.20 | .000 | −1.63 (.13) [-1.89; −1.38] |
| Phase D | −4.02 | .38 | −10.70 | .000 | −1.52 (.14) [-1.80; −1.23] |
| Phase E | −3.92 | .55 | −7.19 | .002 | −1.48 (.21) [-1.90; −1.06] |
| Time | −.01 | .008 | −1.73 | .16 | – |
| **Satisfaction** | | | | | |
| Intercept | 4.18 | .27 | 15.60 | .000 | – |
| Phase B | .17 | .22 | .76 | .49 | .09 (.13) [-.16; .34] |
| Phase C | 1.36 | .28 | 4.86 | .008 | .71 (.17) [.37; 1.05] |
| Phase D | 1.76 | .32 | 5.48 | .005 | .92 (.18) [.57; 1.27] |
| Phase E | 1.57 | .46 | 3.42 | .03 | .82 (.26) [.31; 1.34] |
| Time | .03 | .007 | 3.67 | .02 | – |
| **Symptom Experience** | | | | | |
| Intercept | 4.02 | .32 | 12.50 | .000 | – |
| Phase B | −.12 | .23 | −.52 | .63 | −.06 (.13) [-.31; .19] |
| Phase C | −.41 | .29 | −1.41 | .23 | −.22 (.16) [-.54; .10] |
| Phase D | .81 | .33 | 2.46 | .07 | .43 (.19) [.07; .80] |
| Phase E | .70 | .48 | 1.44 | .22 | .37 (.26) [-.15; .89] |
| Time | .04 | .007 | 5.04 | .007 | – |

*Note.* Phase A=baseline, B=exploration, C=active exposure, D=booster, E=follow-up. BC-SMD=between case standardised mean difference.

Table 5. Contrasts between phases.

| First Phase | Second Phase | Estimate | Standard Error | T-value | p-value | Adjusted p-value | BC-SMD (SE) [95% CI] |
|---|---|---|---|---|---|---|---|
| **Avoidance** | | | | | | | |
| Phase C | Phase B | −3.91 | .29 | −13.6 | .000 | .000 | −1.48 (.12) [-1.70; −1.25] |
| Phase D | Phase B | −3.60 | .31 | −11.70 | .000 | .000 | −1.36 (.12) [-1.59; −1.13] |
| Phase D | Phase C | .31 | .27 | 1.14 | .32 | .36 | .12 (.10) [-.09; .32] |
| Phase E | Phase B | −3.51 | .45 | −7.79 | .001 | .002 | −1.32 (.18) [-.67; −.98] |
| Phase E | Phase C | .41 | .39 | 1.04 | .36 | .36 | .15 (.15) [-.14; .45] |
| Phase E | Phase D | .10 | .26 | .38 | .73 | .61 | .04 (.10) [-.17; .24] |
| **Satisfaction** | | | | | | | |
| Phase C | Phase B | 1.19 | .24 | 4.96 | .008 | .02 | .62 (.18) [.28; .97] |
| Phase D | Phase B | 1.59 | .27 | 5.98 | .004 | .02 | .83 (.16) [.52; 1.14] |
| Phase D | Phase C | .40 | .23 | 1.76 | .15 | .15 | .21 (.14) [-.06; .48] |
| Phase E | Phase B | 1.40 | .38 | 3.67 | .02 | .03 | .74 (.23) [.29; 1.19] |
| Phase E | Phase C | .21 | .33 | .65 | .55 | .37 | .11 (.19) [-.25; .48] |
| Phase E | Phase D | −.19 | .22 | −.84 | .45 | .36 | −.10 (.13) [-.36; .16] |
| **Symptom Experience** | | | | | | | |
| Phase C | Phase B | −.29 | .26 | −1.13 | .32 | .38 | −.15 (.15) [-.44; .13] |
| Phase D | Phase B | .93 | .27 | 3.45 | .03 | .06 | .50 (.15) [.20; .80] |

| First Phase | Second Phase | Estimate | Standard Error | T-value | p-value | Adjusted p-value | BC-SMD (SE) [95% CI] |
|---|---|---|---|---|---|---|---|
| Phase D | Phase C | 1.22 | .24 | 5.09 | .007 | .04 | .65 (.14) [.39; .91] |
| Phase E | Phase B | .82 | .40 | 2.06 | .11 | .17 | .44 (.22) [.01; .86] |
| Phase E | Phase C | 1.11 | .35 | 3.18 | .03 | .06 | .59 (.19) [.22; .96] |
| Phase E | Phase D | −.11 | .23 | −.49 | .65 | .65 | −.06 (.13) [-.31; .19] |

*Note.* Phase A=baseline, B=exploration, C=active exposure, D=booster, E=follow-up. - SMD=between case standardised mean difference.

Table 6. Regression estimates for moderator variables.

| | Estimate | Standard Error | T-value | p-value |
|---|---|---|---|---|
| **Avoidance** | | | | |
| Age | .03 | .03 | .92 | .41 |
| Phase B: Age | .03 | .02 | 1.38 | .24 |
| Phase C: Age | −.01 | .03 | −.29 | .79 |
| Phase D: Age | .01 | .02 | .64 | .56 |
| Phase E: Age | −.00 | .02 | −.09 | .93 |
| Sex F | −2.58 | .66 | −3.91 | .02* |
| Phase B: Sex F | .45 | .62 | .72 | .51 |
| Phase C: Sex F | 2.33 | .66 | 3.52 | .02* |
| Phase D: Sex F | 2.82 | .49 | 5.78 | .004* |
| Phase E: Sex F | 2.91 | .53 | 5.52 | .005* |
| Time injury | −.06 | .06 | −.99 | .38 |
| Phase B: Time injury | −.07 | .06 | −1.17 | .31 |
| Phase C: Time injury | .15 | .06 | 2.36 | .08 |
| Phase D: Time injury | .13 | .05 | 2.79 | .05 |
| Phase E: Time injury | .10 | .05 | 2.23 | .09 |

| | Estimate | Standard Error | T-value | p-value |
|---|---|---|---|---|
| Setting 2 | −1.96 | .79 | −2.48 | .07 |
| Phase B: Setting 2 | .23 | .74 | .31 | .77 |
| Phase C: Setting 2 | 2.70 | .79 | 3.41 | .03* |
| Phase D: Setting 2 | 2.89 | .58 | 4.99 | .008* |
| Phase E: Setting 2 | 3.27 | .60 | 5.43 | .006* |
| Setting 3 | −1.04 | 1.01 | −1.03 | .36 |
| Phase B: Setting 3 | −.19 | .90 | −.22 | .84 |
| Phase C: Setting 3 | .58 | 1.01 | .57 | .60 |
| Phase D: Setting 3 | −.23 | .75 | −.30 | .78 |
| Phase E: Setting 3 | .87 | .73 | 1.18 | .30 |
| Treatment History | −1.44 | .54 | −2.64 | .06 |
| Phase B: Treatment History | .10 | .50 | .20 | .85 |
| Phase C: Treatment History | 1.16 | .55 | 2.13 | .10 |
| Phase D: Treatment History | .62 | .40 | 1.55 | .20 |
| Phase E: Treatment History | 1.17 | .41 | 2.88 | .04* |
| **Satisfaction** | | | | |
| Age | .04 | .03 | 1.45 | .22 |
| Phase B: Age | .02 | .02 | .77 | .48 |
| Phase C: Age | −.02 | .02 | −.85 | .44 |
| Phase D: Age | −.05 | .02 | −2.55 | .06 |
| Phase E: Age | −.01 | .02 | −.56 | .60 |
| Sex F | .17 | .66 | .25 | .81 |
| Phase B: Sex F | −.37 | .53 | −.69 | .53 |
| Phase C: Sex F | .34 | .58 | .60 | .58 |
| Phase D: Sex F | −.06 | .44 | −.15 | .89 |
| Phase E: Sex F | −.64 | .47 | −1.37 | .24 |
| Time injury | −.05 | .06 | −.72 | .51 |
| Phase B: Time injury | .04 | .05 | .77 | .48 |

| | Estimate | Standard Error | T-value | p-value |
|---|---|---|---|---|
| Phase C: Time injury | .05 | .06 | .87 | .44 |
| Phase D: Time injury | −.01 | .04 | −.17 | .87 |
| Phase E: Time injury | −.04 | .04 | −.95 | .40 |
| Setting 2 | −1.56 | .85 | −1.84 | .14 |
| Phase B: Setting 2 | −.03 | .64 | −.04 | .97 |
| Phase C: Setting 2 | 1.27 | .69 | 1.84 | .14 |
| Phase D: Setting 2 | .92 | .52 | 1.78 | .15 |
| Phase E: Setting 2 | .29 | .54 | .54 | .62 |
| Setting 3 | .48 | 1.07 | .45 | .68 |
| Phase B: Setting 3 | −1.00 | .78 | −1.28 | .27 |
| Phase C: Setting 3 | −.42 | .88 | −.48 | .66 |
| Phase D: Setting 3 | .40 | .67 | .60 | .58 |
| Phase E: Setting 3 | −1.13 | .66 | −1.72 | .16 |
| Treatment History | .14 | .55 | .26 | .81 |
| Phase B: Treatment History | −.12 | .43 | −.28 | .80 |
| Phase C: Treatment History | .99 | .47 | 2.09 | .10 |
| Phase D: Treatment History | .57 | .36 | 1.60 | .19 |
| Phase E: Treatment History | −.29 | .36 | −.79 | .47 |
| **Symptom Experience** | | | | |
| Age | .02 | .03 | .83 | .46 |
| Phase B: Age | .01 | .02 | .58 | .59 |
| Phase C: Age | −.01 | .03 | −.50 | .64 |
| Phase D: Age | −.02 | .02 | −.89 | .42 |
| Phase E: Age | −.002 | .02 | −.12 | .91 |
| Sex F | .31 | .70 | .45 | .68 |
| Phase B: Sex F | −.08 | .57 | −.14 | .90 |
| Phase C: Sex F | .001 | .62 | .002 | .99 |
| Phase D: Sex F | .07 | .45 | −.15 | .89 |

| | Estimate | Standard Error | T-value | p-value |
|---|---|---|---|---|
| Phase E: Sex F | −1.38 | .49 | −2.82 | .05 |
| Time injury | −.08 | .07 | −1.19 | .30 |
| Phase B: Time injury | .08 | .05 | 1.55 | .20 |
| Phase C: Time injury | .006 | .06 | .10 | .93 |
| Phase D: Time injury | −.002 | .04 | −.04 | .97 |
| Phase E: Time injury | −.01 | .04 | −.23 | .83 |
| Setting 2 | −1.43 | .84 | −1.70 | .16 |
| Phase B: Setting 2 | .60 | .69 | .88 | .43 |
| Phase C: Setting 2 | 1.13 | .74 | 1.54 | .20 |
| Phase D: Setting 2 | .32 | .54 | .60 | .58 |
| Phase E: Setting 2 | .007 | .56 | .01 | .99 |
| Setting 3 | .31 | 1.07 | .29 | .78 |
| Phase B: Setting 3 | −.87 | .84 | −1.04 | .36 |
| Phase C: Setting 3 | .68 | .94 | .72 | .51 |
| Phase D: Setting 3 | 1.13 | .70 | 1.63 | .18 |
| Phase E: Setting 3 | .29 | .68 | .43 | .69 |
| Treatment History | −.32 | .58 | −.55 | .61 |
| Phase B: Treatment History | .28 | .47 | .59 | .59 |
| Phase C: Treatment History | .51 | .51 | 1.01 | .37 |
| Phase D: Treatment History | .56 | .37 | 1.52 | .20 |
| Phase E: Treatment History | −.26 | .38 | −.68 | .53 |

*Note.* Phase A=baseline, B=exploration, C=active exposure, D=booster, E=follow-up.

## 2.4. Sensitivity analysis

The analyses using the original dataset yielded results that were consistent with those obtained from the imputed dataset, suggesting that the present findings are robust. Minor variations were observed in the analyses, with a few NAP estimates falling into different effect interpretations; the model coefficients were comparable with similar

patterns of statistical significance shown despite minor variations. The results for the original dataset are in the supplementary materials, Tables S2 and S4 to S6.

## 3. Discussion

The present study is the first study, to date, assessing the effectiveness of intensive exposure therapy for patients with PPCS utilising aggregated data of multiple SCEDs. While our first pilot SCED assessing the efficacy of the intensive exposure therapy (King et al., 2024) took place under strictly controlled optimal conditions (i.e., paying for participants activities and hotel, rigorously controlled criteria etc.) with strong internal validity, cross-validation of the results was necessary to better approximate real-world healthcare settings, as was done successfully in the present study.

NAP results showed variation in the results throughout the different phases (from weak to strong effects) and in the combined NAP scores which is corroborated in the violin plots. Multilevel modelling findings demonstrated that the therapy effectively reduced avoidance, increased satisfaction with daily functioning, and reduced symptom burden. The effectiveness of this new therapy innovatively applied to PPCS, provides important empirical validation for the fear-avoidance model in the context of PPCS (Silverberg et al., 2018; Wijenberg et al., 2017, 2020) and suggests that therapies targeting psychological factors of fear-avoidance and catastrophising (Hecker et al., 2025) can lead to meaningful improvements in patients' daily lives in this population. The improvements in avoidance and satisfaction occur in the active exposure phase (C), while increased positive experiences of symptoms (increased functioning) are seen in the booster (D) or follow-up (E) phases. These improvements are not solely due to providing attention to symptoms (placebo response). Overall, these findings suggest that improvements may be visible after a relatively short period of therapy, potentially faster than treatment as usual, which could allow for earlier return to work and greater societal participation, possibly reducing related health and societal burdens. These effects underscore the need for specific, personalized exposure-based treatments for individuals with PPCS, rather than merely relying on education or supportive attention, aligning with findings of previous studies (Heslot et al., 2022; Rytter et al., 2021; Snell et al., 2009).

Moderation analyses revealed that females avoided significantly less than men at baseline (A), while males showed greater reductions in avoidance during the active exposure (C), booster (D), and follow-up (E) phases than women. One possible explanation for this finding may be due to baseline differences in avoidance, suggesting that females had less room for improvement during the therapy compared to males, therefore reductions may have been less noticeable for females. This aligns with previous research suggesting greater benefits of exposure therapy (targeting other disorders such as fibromyalgia, psychosis, anxiety) when there is more room for improvement (Berkhof

et al., 2025; Hedman-Lagerlöf et al., 2023). Another explanation may be due to the unequal size of the sample with more females taking part in the study than men. This may have affected baseline comparisons and the magnitude of the observed changes. Participants with a history of mental health treatment experienced significantly worse outcomes on avoidance during the follow-up phase (E) compared to those without a history of mental health treatment. This could be due to greater psychological inflexibility, or more entrenched avoidance patterns in individuals with a history of mental health concerns (Epe-Jungeblodt et al., 2024; Schwartz et al., 2024). Participants treated at Heliomare showed significantly less improvement in avoidance compared to those in the university setting during the active exposure (C), booster (D), and follow-up (E) phases. This may have been a direct influence of participants being away from their regular environments (staying at a hotel) in the university setting, whereas in Heliomare, two of the participants chose to return home daily after therapy. There were no significant differences in avoidance related to age, time since injury, or treatment setting (for those treated at Klimmendaal compared to those at the university setting). Furthermore, none of the moderators or interactions were significantly different across participants for satisfaction or symptom experience. Our findings support previous research indicating a lack of clear evidence for demographic moderators in exposure therapy (Schneider et al., 2015). Encouragingly, the moderation analyses in the present study suggested that patients of varying ages (up until 59 as per this study) and durations since injury may benefit from the therapy.

Our intensive exposure therapy directly targets participants' negative expectations and fear predictions by linking them explicitly to the outcomes of exposure experiments. When these predicted fears do not occur, participants learn that their expectations are false, leading to expectancy learning and reductions in avoidance behaviours (Craske et al., 2014, 2022). By focusing specifically on the fear-avoidance mechanisms that sustain PPCS, our intensive exposure therapy, grounded in the fear-avoidance model, offers a psychologically targeted and accessible alternative to the broader neurorehabilitation models which mainly emphasise physiological recovery. Furthermore, personality characteristics such as high anxiety sensitivity and pain catastrophising have been associated to worse outcomes following mTBI (Mavroudis et al., 2024). Given this, psychoeducation which incorporates explanations of fear-avoidance mechanisms in PPCS may be particularly beneficial for individuals at risk of developing PPCS. The observed effectiveness of the intensive exposure therapy further supports the clinical relevance of these psychological predictors, as they are indirectly addressed through the therapeutic process.

In addition to the intensive exposure programme, several unique elements were added to the therapy to improve the therapy effects and optimise exposure mechanisms (Craske et al., 2022). Therapist rotation was utilised which has been shown to reduce therapist drift,

provide strong therapeutic alliance, and allow participants to experience different perspectives (Auren et al., 2022), thereby improving generalisation of therapy effects. Other elements, such as removing participants from their daily routine (staying in a hotel), having their significant others involved in the therapy, and encouraging continuous activity throughout the exposure week beyond the scheduled sessions may assist in the overall therapy effect shown in the present study. These elements were intentionally incorporated into the therapy to improve therapeutic benefits and should be included in clinical applications of exposure therapy (where possible), and future studies. Additionally, while the therapy was successfully applied across different settings in this study with no adverse events occurring, it is important to note that the therapy was performed by psychologists and should be provided by those with experience with exposure therapy. The present study expands the limited evidence supporting exposure therapy for PPCS (Hecker et al., 2024; Silverberg et al., 2022), novelly highlighting the benefits of an intensive (brief) version administered over a shorter period of time, in this patient group. This is particularly valuable in light of the lengthy time participants often spend seeking help, relative to the short period of time participants spend in this effective therapy. Furthermore, as time since injury was not a moderating factor in this study, the therapy can be successfully applied to those from 3 months to 24 months after injury.

In the present study, hypotheses were tested across 5 studies with 20 participants in total yielding a large amount of data and utilising a rigorous multi-phase design. This design included a control phase (providing attention to participants' problems) to account for possible placebo responses, in addition to the control already provided for by the baseline phase. To account for missing data, which is common in SCED studies (Aydin, 2024b), analyses were conducted on imputed datasets using multiple imputation methods (Aydin, 2024a) – a relatively novel application within this context. Non-overlap of all pairs and multilevel modelling were conducted, allowing the results from the different studies to be aggregated using a robust, innovative approach. Sensitivity analysis revealed that the results were comparable between the imputed and original datasets, adding to the robustness of the results. While this study provides evidence suggesting the intervention may be effective for PPCS after mTBI, the study has some limitations. VAS scales were utilised for daily assessments and participants were not blinded to the numerical values, therefore some response bias may have been present (Simons et al., 2020; Sung & Wu, 2018). To limit this, participants were not able to see their previous scores. Additionally, the samples in the present studies were culturally homogeneous, and while this is representative for the country in which the studies took place, future research may assess the effectiveness of this therapy with more culturally diverse groups. Future research is also needed to identify the specific indication criteria

to determine which individuals with PPCS should receive exposure therapy (for instance those with higher avoidance behaviours).

The rigorous study design and robust statistical techniques of the present study suggest potential benefits of this innovative intensive exposure therapy targeting PPCS. The findings further support the relevance of the fear-avoidance model to PPCS and contribute to the growing evidence that exposure therapy may be beneficial for this patient population.

## CRediT authorship contribution statement

**Skye King:** Writing – original draft, Visualization, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Marleen Rijkeboer:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **Ieke Winkens:** Writing – review & editing, Supervision, Methodology, Conceptualization. **Nora Tuts:** Writing – review & editing, Visualization, Project administration, Methodology, Investigation, Data curation, Conceptualization. **Marthe Ford:** Writing – review & editing, Project administration, Methodology, Investigation. **Nikita Frankenmolen:** Writing – review & editing, Project administration, Methodology, Investigation. **René Tanious:** Writing – review & editing, Validation. **Joukje van der Naalt:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Conceptualization. **Caroline van Heugten:** Writing – review & editing, Supervision, Project administration, Methodology, Investigation, Funding acquisition, Conceptualization.

## Statement of ethics

This work complied with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki declaration of 1975, as revised in 2013. This study was approved by the Ethical Review Committee of Psychology and Neuroscience of Maastricht University, approval numbers ERCPN 250_44_03–2022; 250_44_03_2022_A2; 275_132_12_2023; 275_132_12_2023_A2, and the local ethics committees of the rehabilitation centres. Each participant provided written informed consent.

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## 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.

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## Appendix A. Supplementary data

The following is the Supplementary data to this article:

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Multimedia component 1.

Recommended articles

## Data availability

Data will be made available on request.

## References

Anderson and Fitzgerald, 2020 J.F. Anderson, P. Fitzgerald

Associations between coping style, illness perceptions and self-reported symptoms after mild traumatic brain injury in prospectively studied pre-morbidly healthy individuals

Neuropsychological Rehabilitation, 30 (6) (2020), pp. 1115-1128

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Archer et al., 2019 B. Archer, J.H. Azios, N. Müller, L. Macatangay

Effect sizes in single-case aphasia studies: A comparative, autocorrelation-oriented analysis

Journal of Speech, Language, and Hearing Research, 62 (7) (2019), pp. 2473-2482

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Auren et al., 2022 T.J.B. Auren, J.R. Klæth, A.G. Jensen, S. Solem

Intensive outpatient treatment for PTSD: An open trial combining prolonged exposure therapy, EMDR, and physical activity

European Journal of Psychotraumatology, 13 (2) (2022), Article 2128048

View in Scopus ↗ Google Scholar ↗

Aydin, 2024a O. Aydin

Characteristics of missing data in single-case experimental designs: An investigation of published data

Behavior Modification, 48 (2) (2024), pp. 182-215

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Aydin, 2024b O. Aydin

A description of missing data in single-case experimental designs studies and an evaluation of single imputation methods

Behavior Modification, 48 (3) (2024), pp. 312-359

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Baek et al., 2023 E. Baek, W. Luo, K.H. Lam

Meta-analysis of single-case experimental design using multilevel modeling

Behavior Modification, 47 (6) (2023), pp. 1546-1573

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Bates et al., 2015 D. Bates, M. Mächler, B. Bolker, S. Walker

Fitting linear mixed-effects models using lme4

Journal of Statistical Software, 67 (1) (2015), pp. 1-48, 10.18637/jss.v067.i01 ↗

Google Scholar ↗

Benjamini and Hochberg, 2000 Y. Benjamini, Y. Hochberg

On the adaptive control of the false discovery rate in multiple testing with independent statistics

Journal of Educational and Behavioral Statistics, 25 (1) (2000), pp. 60-83

View in Scopus ↗ Google Scholar ↗

Berkhof et al., 2025 M. Berkhof, E. van der Stouwe, R. Pot-Kolder, M. van der Gaag, W. Veling, C. Geraets

Exploring the role of clinical and demographic characteristics on the effects of virtual reality cognitive behavioral therapy for psychosis: A moderator analysis

Acta Psychiatrica Scandinavica, 151 (3) (2025), pp. 293-303

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Blanchard et al., 2023 MuToss Coding Team, G. Blanchard, T. Dickhaus, N. Hack, F. Konietschke, K. Rohmeyer, J. Rosenblatt, M. Scheer, W. W

Mutoss: Unified multiple testing procedures

R package version 0 (2023), pp. 1-13

https://CRAN.R-project.org/package=mutoss ↗

Google Scholar ↗

Cancelliere et al., 2023 C. Cancelliere, L. Verville, J.L. Stubbs, H. Yu, C.A. Hincapié, J.D. Cassidy, J.J. Wong, H.M. Shearer, G. Connell, D. Southerst, S. Howitt, B. Guist, N.D. Silverberg

Post-concussion symptoms and disability in adults with mild traumatic brain injury: A systematic review and meta-analysis

Journal of Neurotrauma, 40 (11–12) (2023), pp. 1045-1059, 10.1089/neu.2022.0185 ↗

View in Scopus ↗ Google Scholar ↗

Cnossen et al., 2018 M.C. Cnossen, J. van der Naalt, J.M. Spikman, D. Nieboer, J.K. Yue, E.A. Winkler, G.T. Manley, N. Von Steinbuechel, S. Polinder, E.W. Steyerberg

Prediction of persistent post-concussion symptoms after mild traumatic brain injury

Journal of Neurotrauma, 35 (22) (2018), pp. 2691-2698

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Craske et al., 2012 M.G. Craske, B. Liao, L. Brown, B. Vervliet

Role of inhibition in exposure therapy

Journal of Experimental Psychopathology, 3 (3) (2012), pp. 322-345, 10.5127/jep.026511 ↗

View in Scopus ↗ Google Scholar ↗

Craske et al., 2014 M.G. Craske, M. Treanor, C.C. Conway, T. Zbozinek, B. Vervliet

Maximizing exposure therapy: An inhibitory learning approach

Behaviour Research and Therapy, 58 (2014), pp. 10-23, 10.1016/j.brat.2014.04.006 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

Craske et al., 2022 M.G. Craske, M. Treanor, T.D. Zbozinek, B. Vervliet

Optimizing exposure therapy with an inhibitory retrieval approach and the OptEx Nexus

Behaviour Research and Therapy, 152 (2022), Article 104069, 10.1016/j.brat.2022.104069 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

De et al., 2020 T.K. De, B. Michiels, R. Tanious, P. Onghena

Handling missing data in randomization tests for single-case experiments: A simulation study

Behavior Research Methods, 52 (2020), pp. 1355-1370

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Dodd et al., 2001 M. Dodd, S. Janson, N. Facione, J. Faucett, E.S. Froelicher, J. Humphreys, K. Lee, C. Miaskowski, K. Puntillo, S. Rankin, D. Taylor

Advancing the science of symptom management

Journal of Advanced Nursing, 33 (5) (2001), pp. 668-676, 10.1046/j.1365-2648.2001.01697.x ↗

View in Scopus ↗ Google Scholar ↗

Epe-Jungeblodt et al., 2024 F. Epe-Jungeblodt, P. Pauli, F. Schwab, M. Andreatta

Trauma history and course of therapy in a naturalistic cognitive behavior therapy outpatient sample: An archive data study

Journal of Clinical Psychology, 80 (8) (2024), pp. 1937-1948, 10.1002/jclp.23702 ↗

View in Scopus ↗ Google Scholar ↗

Fallesen and Campos, 2020 P. Fallesen, B. Campos

Effect of concussion on salary and employment: A population-based event time study using a quasi-experimental design

BMJ Open, 10 (10) (2020), Article e038161

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Hecker et al., 2024 L. Hecker, S. King, S. Stapert, C. Geusgens, M. den Hollander, B. Fleischeuer, C. van Heugten

Can exposure therapy be effective for persistent post-concussion symptoms? A nonconcurrent multiple baseline design across 4 cases

The Journal of Head Trauma Rehabilitation, 10 (2024), p. 1097

Google Scholar ↗

Hecker et al., 2025 L. Hecker, S. King, M. Wijenberg, C. Geusgens, S. Stapert, J. Verbunt, C. Van Heugten

Catastrophizing thoughts and fear-avoidance behavior are related to persistent post-concussion symptoms after mild traumatic brain injury

Neurotrauma Reports, 6 (1) (2025), pp. 148-157

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Hedges et al., 2012 L.V. Hedges, J.E. Pustejovsky, W.R. Shadish

A standardized mean difference effect size for single case designs

Research Synthesis Methods, 3 (3) (2012), pp. 224-239

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Hedges et al., 2010 L.V. Hedges, E. Tipton, M.C. Johnson

Robust variance estimation in meta-regression with dependent effect size estimates

Research Synthesis Methods, 1 (1) (2010), pp. 39-65

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Hedman-Lagerlöf et al., 2023 M. Hedman-Lagerlöf, E. Andersson, B. Ljótsson, J. Engelbrektsson, K. Lundbäck, D. Björkander, E. Hedman-Lagerlöf, I. Flink, E. Axelsson

Effect moderators in internet-based exposure therapy for fibromyalgia: The role of pain intensity

European Journal of Pain, 27 (4) (2023), pp. 507-517, 10.1002/ejp.2074 ↗

View in Scopus ↗ Google Scholar ↗

Hendriks et al., 2018 L. Hendriks, R.A.d. Kleine, T.G. Broekman, G.-J. Hendriks, A.v. Minnen

Intensive prolonged exposure therapy for chronic PTSD patients following multiple trauma and multiple treatment attempts

European Journal of Psychotraumatology, 9 (1) (2018), Article 1425574, 10.1080/20008198.2018.1425574 ↗

View in Scopus ↗ Google Scholar ↗

Heslot et al., 2022 C. Heslot, P. Azouvi, V. Perdrieau, A. Granger, C. Lefèvre-Dognin, M. Cogné

A systematic review of treatments of post-concussion symptoms

Journal of Clinical Medicine, 11 (20) (2022), p. 6224

https://www.mdpi.com/2077-0383/11/20/6224 ↗

Crossref ↗ View in Scopus ↗ Google Scholar ↗

King et al., 2024 S. King, S.Z. Stapert, I. Winkens, J. van der Naalt, C.M. van Heugten, M.M. Rijkeboer

Efficacy of an intensive exposure intervention for individuals with persistent concussion symptoms following concussion: A concurrent multiple baseline single-case experimental design (SCED) Study

The Journal of Head Trauma Rehabilitation, 39 (5) (2024), pp. E419-E429, 10.1097/HTR.0000000000000942 ↗

View in Scopus ↗ Google Scholar ↗

Knowles and Tolin, 2022 K.A. Knowles, D.F. Tolin

Mechanisms of action in exposure therapy

Current Psychiatry Reports, 24 (12) (2022), pp. 861-869, 10.1007/s11920-022-01391-8 ↗

View in Scopus ↗ Google Scholar ↗

Krampe and Ehrenreich, 2012 H. Krampe, H. Ehrenreich

Therapeutic alliance and multiple psychotherapy in the context of therapist rotation: Experiences with OLITA

Neurology Psychiatry and Brain Research, 18 (4) (2012), pp. 137-152

View PDF View article View in Scopus ↗ Google Scholar ↗

Kuznetsova et al., 2017 A. Kuznetsova, P.B. Brockhoff, R.H. Christensen

lmerTest package: Tests in linear mixed effects models

Journal of Statistical Software, 82 (2017), pp. 1-26

View in Scopus ↗ Google Scholar ↗

Leeuw et al., 2008 M. Leeuw, M.E.J.B. Goossens, G.J.P. van Breukelen, J.R. de Jong, P.H.T.G. Heuts, R.J.E.M. Smeets, A.J.A. Köke, J.W.S. Vlaeyen

Exposure in vivo versus operant graded activity in chronic low back pain patients: Results of a randomized controlled trial

Pain, 138 (1) (2008), pp. 192-207, 10.1016/j.pain.2007.12.009 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

Lenth, 2025 R. Lenth

Emmeans: Estimated marginal means, aka least-squares means

https://rvlenth.github.io/emmeans/ ↗ (2025)

Google Scholar ↗

Lumley, 2019 T. Lumley

Mitools: Tools for multiple imputation of missing data

https://CRAN.R-project.org/package=mitools ↗ (2019)

Google Scholar ↗

Manolov and Moeyaert, 2017 R. Manolov, M. Moeyaert

How can single-case data be analyzed? Software resources, tutorial, and reflections on analysis

Behavior Modification, 41 (2) (2017), pp. 179-228

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Mavroudis et al., 2024 I. Mavroudis, S. Chatzikonstantinou, F. Petridis, I.-M. Balmus, A. Ciobica

A review of the personality traits in post-concussion syndrome

Acta Neurologica Belgica, 124 (3) (2024), pp. 791-802

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Mestdagh et al., 2023 M. Mestdagh, S. Verdonck, M. Piot, K. Niemeijer, G. Kilani, F. Tuerlinckx, P. Kuppens, E. Dejonckheere

m-Path: An easy-to-use and highly tailorable platform for ecological momentary assessment and intervention in behavioral research and clinical practice

Frontiers in Digital Health, 5 (2023), Article 1182175, 10.3389/fdgth.2023.1182175 ↗

View in Scopus ↗ Google Scholar ↗

Moeyaert et al., 2020 M. Moeyaert, R. Manolov, E. Rodabaugh

Meta-analysis of single-case research via multilevel models: Fundamental concepts and methodological considerations

Behavior Modification, 44 (2) (2020), pp. 265-295

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Parker and Vannest, 2009 R.I. Parker, K. Vannest

An improved effect size for single-case research: Nonoverlap of all pairs

Behavior Therapy, 40 (4) (2009), pp. 357-367, 10.1016/j.beth.2008.10.006 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

Parker et al., 2011 R.I. Parker, K.J. Vannest, J.L. Davis

Effect size in single-case research: A review of nine nonoverlap techniques

Behavior Modification, 35 (4) (2011), pp. 303-322, 10.1177/0145445511399147 ↗

View in Scopus ↗ Google Scholar ↗

Peng and Chen, 2018 C.-Y.J. Peng, L.-T. Chen

Handling missing data in single-case studies

Journal of Modern Applied Statistical Methods, 17 (1) (2018), p. 5

View in Scopus ↗ Google Scholar ↗

Peng and Chen, 2021 C.-Y.J. Peng, L.-T. Chen

Assessing intervention effects in the presence of missing scores

Education Sciences, 11 (2) (2021), p. 76

Crossref ↗ Google Scholar ↗

Pinheiro et al., 2025 J. Pinheiro, D. Bates, R.c. Team

Nlme: Linear and nonlinear mixed effects models

https://CRAN.R-project.org/package=nlme ↗ (2025)

Google Scholar ↗

Polinder et al., 2018 S. Polinder, M.C. Cnossen, R.G.L. Real, A. Covic, A. Gorbunova, D.C. Voormolen, C.L. Master, J.A. Haagsma, R. Diaz-Arrastia, N. von Steinbuechel

A multidimensional approach to post-concussion symptoms in mild traumatic brain injury

Frontiers in Neurology, 9 (2018), 10.3389/fneur.2018.01113 ↗

[Review]

Google Scholar ↗

Ponsford et al., 2019 J. Ponsford, S. Nguyen, M. Downing, M. Bosch, J.E. McKenzie, S. Turner, M. Chau, D. Mortimer, R.L. Gruen, J. Knott

Factors associated with persistent post-concussion symptoms following mild traumatic brain injury in adults

Journal of Rehabilitation Medicine, 51 (1) (2019), pp. 32-39

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Pustejovsky, 2019 J.E. Pustejovsky

Procedural sensitivities of effect sizes for single-case designs with directly observed behavioral outcome measures

Psychological Methods, 24 (2) (2019), p. 217

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Pustejovsky et al., 2024 J.E. Pustejovsky, M. Chen, D.M. Swan
SingleCaseES: A calculator for single-case effect sizes
(0.7.3.9999 ed.) (2024)
https://jepusto.github.io/SingleCaseES/ ↗
Google Scholar ↗

R Core Team, 2021 R Core Team
R: A language and environment for statistical computing
R Foundation for Statistical Computing (2021)
https://www.R-project.org/ ↗
Google Scholar ↗

Rijkeboer and van den Hout, 2014 M.M. Rijkeboer, M.A. van den Hout
Nieuwe inzichten over exposure
Gedragstherapie, 47 (1) (2014), pp. 2-19
Google Scholar ↗

Rioux et al., 2024 M. Rioux, P.M. Brasher, G. McKeown, K.O. Yeates, A.-M. Vranceanu, D.L. Snell, M. Cairncross, W.J. Panenka, G.L. Iverson, C.T. Debert
Graded exposure therapy for adults with persistent symptoms after mTBI: A historical comparison study
Neuropsychological Rehabilitation (2024), pp. 1-17
View in Scopus ↗ Google Scholar ↗

Rubin, 1987 D.B. Rubin
Multiple imputation for nonresponse in surveys
John Wiley & Sons, Inc (1987), 10.1002/9780470316696 ↗
Google Scholar ↗

Rytter et al., 2021 H.M. Rytter, H.J. Graff, H.K. Henriksen, N. Aaen, J. Hartvigsen, M. Hoegh, I. Nisted, E.T. Næss-Schmidt, L.L. Pedersen, H.W. Schytz, M.M. Thastum, B. Zerlang, H.E. Callesen
Nonpharmacological treatment of persistent postconcussion symptoms in adults: A systematic Review and Meta-analysis and Guideline recommendation
JAMA Network Open, 4 (11) (2021), 10.1001/jamanetworkopen.2021.32221 ↗
e2132221-e2132221
Google Scholar ↗

Schneider et al., 2015 R.L. Schneider, J.J. Arch, K.B. Wolitzky-Taylor
The state of personalized treatment for anxiety disorders: A systematic review of treatment moderators

Clinical Psychology Review, 38 (2015), pp. 39-54, 10.1016/j.cpr.2015.02.004 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

Schwartz et al., 2024 E.K.C. Schwartz, A.N. Palmisano, I.L. Petrakis, R.H. Pietrzak, M. Sofuoglu

Health correlates of experiential and behavioral avoidance among trauma-exposed veterans

Journal of Psychiatric Research, 176 (2024), pp. 213-217, 10.1016/j.jpsychires.2024.06.014 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

Sheldrake et al., 2022 E. Sheldrake, H. Al-Hakeem, B. Lam, B.I. Goldstein, A.L. Wheeler, M. Burke, B.T. Dunkley, N. Reed, S.E. Scratch

Mental health outcomes across the lifespan in individuals with persistent post-concussion symptoms: A scoping review

Frontiers in Neurology, 13 (2022), Article 850590

View in Scopus ↗ Google Scholar ↗

Silverberg et al., 2022 N.D. Silverberg, M. Cairncross, P.M. Brasher, A.-M. Vranceanu, D.L. Snell, K.O. Yeates, W.J. Panenka, G.L. Iverson, C.T. Debert, M.T. Bayley

Feasibility of concussion rehabilitation approaches tailored to psychological coping styles: A randomized controlled trial

Archives of Physical Medicine and Rehabilitation, 103 (8) (2022), pp. 1565-1573. e1562

View in Scopus ↗ Google Scholar ↗

Silverberg and Mikolić, 2023 N.D. Silverberg, A. Mikolić

Management of psychological complications following mild traumatic brain injury

Current Neurology and Neuroscience Reports, 23 (3) (2023), pp. 49-58, 10.1007/s11910-023-01251-9 ↗

View in Scopus ↗ Google Scholar ↗

Silverberg et al., 2018 N.D. Silverberg, W.J. Panenka, G.L. Iverson

Fear avoidance and clinical outcomes from mild traumatic brain injury

Journal of Neurotrauma, 35 (16) (2018), pp. 1864-1873, 10.1089/neu.2018.5662 ↗

View in Scopus ↗ Google Scholar ↗

Simons et al., 2020 L.E. Simons, J.W.S. Vlaeyen, L. Declercq, A.M. Smith, J. Beebe, M. Hogan, E. Li, C.A. Kronman, F. Mahmud, J.R. Corey, C.B. Sieberg, C. Ploski

Avoid or engage? Outcomes of graded exposure in youth with chronic pain using a sequential replicated single-case randomized design

Pain, 161 (3) (2020), pp. 520-531, 10.1097/j.pain.0000000000001735 ↗

View in Scopus ↗ Google Scholar ↗

Snell et al., 2023 D.L. Snell, J.W. Faulkner, J.A. Williman, N.D. Silverberg, A. Theadom, L.J. Surgenor, J. Hackney, R.J. Siegert

Fear avoidance and return to work after mild traumatic brain injury

Brain Injury, 37 (6) (2023), pp. 541-550, 10.1080/02699052.2023.2180663 ↗

View in Scopus ↗ Google Scholar ↗

Snell et al., 2009 D.L. Snell, L.J. S, E.J.C. H.-S, R.J. Siegert

A systematic review of psychological treatments for mild traumatic brain injury: An update on the evidence

Journal of Clinical and Experimental Neuropsychology, 31 (1) (2009), pp. 20-38, 10.1080/13803390801978849 ↗

View in Scopus ↗ Google Scholar ↗

Sung and Wu, 2018 Y.-T. Sung, J.-S. Wu

The visual analogue scale for rating, ranking and paired-comparison (VAS-RRP): A new technique for psychological measurement

Behavior Research Methods, 50 (2018), pp. 1694-1715

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Tanious et al., 2019 R. Tanious, T.K. De, P. Onghena

A multiple randomization testing procedure for level, trend, variability, overlap, immediacy, and consistency in single-case phase designs

Behaviour Research and Therapy, 119 (2019), Article 103414, 10.1016/j.brat.2019.103414 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

Tanious and Manolov, 2022 R. Tanious, R. Manolov

Violin plots as visual tools in the meta-analysis of single-case experimental designs

Methodology, 18 (3) (2022), pp. 221-238

Crossref ↗ View in Scopus ↗ Google Scholar ↗

Tanious and Manolov, 2025 R. Tanious, R. Manolov

Visual analysis of single-case experimental designs data: Beyond time-series graphs

Single Case in the Social Sciences, 2 (1) (2025), pp. 43-64

Crossref ↗ Google Scholar ↗

Tate et al., 2019 R. Tate, M. Perdices, U. Rosenkoetter, W. Shadish, S. Vohra, D. Barlow, R. Horner, A. Kazdin, T. Kratochwill, S. McDonald

The single-case reporting guideline in behavioural interventions (SCRIBE) 2016 statement

Pratiques Psychologiques, 25 (2) (2019), pp. 103-117

View PDF View article View in Scopus ↗ Google Scholar ↗

Tate et al., 2015 R. Tate, U. Rosenkoetter, D. Wakim, L. Sigmundsdottir, J. Doubleday, L. Togher, S. McDonald, M. Perdices

The risk-of-bias in N-of-1 trials (RoBiNT) Scale: An expanded manual for the critical appraisal of single-case reports

(2015)

Google Scholar ↗

Terpstra et al., 2021 A.R. Terpstra, M. Cairncross, K.O. Yeates, A.M. Vranceanu, J. Greenberg, C. Hunt, N.D. Silverberg

Psychological mediators of avoidance and endurance behavior after concussion

Rehabilitation Psychology, 66 (4) (2021), pp. 470-478, 10.1037/rep0000390 ↗

View in Scopus ↗ Google Scholar ↗

Treanor and Barry, 2017 M. Treanor, T.J. Barry

Treatment of avoidance behavior as an adjunct to exposure therapy: Insights from modern learning theory

Behaviour Research and Therapy, 96 (2017), pp. 30-36, 10.1016/j.brat.2017.04.009 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

Valentine et al., 2016 J.C. Valentine, E.E. Tanner-Smith, J.E. Pustejovsky, T.S. Lau

Between-case standardized mean difference effect sizes for single-case designs: A primer and tutorial using the scdhlm web application

Campbell Systematic Reviews, 12 (1) (2016), pp. 1-31

Crossref ↗ Google Scholar ↗

van Buuren and Groothuis-Oudshoorn, 2011 S. van Buuren, K. Groothuis-Oudshoorn

Mice: Multivariate imputation by chained equations in R

Journal of Statistical Software, 45 (3) (2011), pp. 1-67, 10.18637/jss.v045.i03 ↗

View in Scopus ↗ Google Scholar ↗

Van den Noortgate and Onghena, 2007 W. Van den Noortgate, P. Onghena

The aggregation of single-case results using hierarchical linear models

Behavior Analyst Today, 8 (2) (2007), pp. 196-209, 10.1037/h0100613 ↗

Google Scholar ↗

van der Vlegel et al., 2021 M. van der Vlegel, S. Polinder, H. Toet, M.J. Panneman, J.A. Haagsma

Prevalence of post-concussion-like symptoms in the general injury population and the association with health-related quality of life, health care use, and return to work

Journal of Clinical Medicine, 10 (4) (2021), p. 806

Crossref ↗ Google Scholar ↗

Van Minnen et al., 2018 A. Van Minnen, L. Hendriks, R.D. Kleine, G.-J. Hendriks, M. Verhagen, A. De Jongh

Therapist rotation: A novel approach for implementation of trauma-focused treatment in post-traumatic stress disorder

European Journal of Psychotraumatology, 9 (1) (2018), Article 1492836, 10.1080/20008198.2018.1492836 ↗

View in Scopus ↗ Google Scholar ↗

Vermeer et al., 2025 F. Vermeer, N. Frankenmolen, T. Coppes, J. Schuurman, D. Bertens

The role of illness perceptions in post-concussive symptoms in the chronic phase after mild traumatic brain injury (mTBI)

Brain Impairment, 26 (2) (2025), 10.1071/IB24038 ↗

Google Scholar ↗

Voormolen et al., 2019 D.C. Voormolen, S. Polinder, N. von Steinbuechel, P.E. Vos, M.C. Cnossen, J.A. Haagsma

The association between post-concussion symptoms and health-related quality of life in patients with mild traumatic brain injury

Injury, 50 (5) (2019), pp. 1068-1074, 10.1016/j.injury.2018.12.002 ↗

View PDF View article View in Scopus ↗ Google Scholar ↗

Wickham, 2016 H. Wickham

ggplot2: Elegant graphics for data analysis

Springer-Verlag, New York (2016)

https://ggplot2.tidyverse.org ↗

Google Scholar ↗

Wijenberg et al., 2020 M.L.M. Wijenberg, A.J. Hicks, M.G. Downing, C.M. van Heugten, S.Z. Stapert, J.L. Ponsford

Relevance of the fear-avoidance model for chronic disability after traumatic brain injury

Journal of Neurotrauma, 37 (24) (2020), pp. 2639-2646, 10.1089/neu.2020.7135 ↗

View in Scopus ↗ Google Scholar ↗

Wijenberg et al., 2017 M.L.M. Wijenberg, S.Z. Stapert, J.A. Verbunt, J.L. Ponsford, C.M. Van Heugten

Does the fear avoidance model explain persistent symptoms after traumatic brain injury?

Brain Injury, 31 (12) (2017), pp. 1597-1604, 10.1080/02699052.2017.1366551 ↗

View in Scopus ↗ Google Scholar ↗

Zigmond and Snaith, 1983 A.S. Zigmond, R.P. Snaith

The hospital anxiety and depression scale

Acta Psychiatrica Scandinavica, 67 (6) (1983), pp. 361-370, 10.1111/j.1600-0447.1983.tb09716.x ↗

View in Scopus ↗ Google Scholar ↗

## Cited by (0)