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research master

Master's thesis

When Memories Take Centre Stage: The Role of Frequent Retrieval, Accessibility, and Event Centrality in the Development of Involuntary Memories

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Are there deviations of the Master's thesis from the proposed plan?
☐No
☒Yes, please explain below the deviations

I analysed two datasets instead of one, because we introduced a second round of data collection due to issues with the sample size. For one of the questionnaires we used,

we slightly adapted instructions. This meant that the data from the two rounds could not be combined and had to be analysed separately.

Abstract

Nearly two decades ago, Berntsen and Rubin (2006) launched a theory of traumatic memories, in which they argued that event centrality is responsible for the development and persistence of post-traumatic stress symptoms such as involuntary memories. Previous research provides correlational evidence for the proposed relationships, but causal evidence crucial for developing therapeutic interventions is still lacking. The current study introduces a new, experimental approach to investigate how frequent retrieval is related to a memory's event centrality, accessibility, and the occurrence of involuntary memories. A total of 30 participants with a mean age of 20 years old took part in a within-subjects experiment. They recalled six personal memories (three negative and three positive) and answered questions about each of the memories during three lab sessions (baseline, post-experiment, one-week follow-up). Between the first two sessions, they frequently retrieved one of the positive memories for six days, whenever they received a notification from an online application. Repeated measures ANOVA was used to analyse the data – split into two datasets. The results yielded no statistically significant effect of frequent retrieval on memory accessibility, event centrality, and the occurrence of involuntary memories. Combining this with the methodological complications encountered during data collection, the evidence found in this study is inconclusive. Theoretical and methodological implications are discussed, as well as limitations and recommendations for future research on this topic.

Keywords: *event centrality, traumatic memories, accessibility, involuntary memories, frequent retrieval, autobiographic memory, Berntsen and Rubin.*

When Memories Take Centre Stage: The Role of Frequent Retrieval, Accessibility, and Event Centrality in the Development of Involuntary Memories

An estimated 70 percent of the worldwide population will experience at least one potentially traumatic event (PTE) in their lifetime (World Health Organization, 2024). Events are potentially traumatic when they have the capacity to cause severe emotional distress to those experiencing them. Examples of PTEs include war, accidents, natural disasters or sexual violence. One consequence of experiencing a potentially traumatic event is developing post-traumatic stress symptoms such as involuntary memories (Mew et al., 2022; Ouagazzal et al., 2021). Involuntary memories, also known as intrusive memories, are memories that come to mind spontaneously and are typically triggered by situational cues (Berntsen, 1996; Berntsen & Nielsen, 2022). Here, the term 'involuntary memories' is preferred over 'intrusions', as the latter often carries a negative connotation in trauma literature. Indeed, the occurrence of involuntary memories can be distressing when the memory has highly negative content, but it is a natural en often neutral process by itself. For most people who experience a trauma, involuntary memories of the event subside over time, yet for a small proportion of people they can last for years on end (Mews et al., 2022; World Health Organization, 2024), to the point that it can impairs daily functioning. There are several theoretical frameworks for the development and persistence of involuntary memories, each with their own underlying mechanisms. These mechanisms have important implications for the development of appropriate interventions for reducing involuntary memories of traumatic events, and therefore, it is important to investigate them.

One line of research suggests that *event centrality* is a predictor of involuntary memories (Berntsen & Rubin, 2006, 2007). Event centrality relates to the meaning people attribute to experienced events and consists of the extent to which the event 1) becomes a reference point for other experiences and future expectations, 2) is integrated into one's

identity, and 3) is viewed as a turning point in one's life story (Berntsen & Rubin, 2006, 2007). The event centrality theory suggests that specific properties of (traumatic) memories are enabling the memory to become overly-well integrated into autobiographical memory by forming several links to other memories as a reference point (Berntsen et al., 2003). When this happens, the memory becomes a "landmark" (i.e. more central) in the organisation of autobiographical memory, which affects the interpretation of less distinct and new experiences. As a result, individuals may begin to view other life experiences and parts of their identity through a trauma-related lens.

Functions of Autobiographic Memory and their Relation to Event Centrality

The theory of event centrality (Berntsen & Rubin, 2006) draws on more general theoretical frameworks of autobiographic memory. Autobiographic memory refers to the part of human memory that serves as an integrated knowledge base for remembering personal events and experiences as well as conceptual ideas about the self and one's life (Conway, 2005). Autobiographic memory is functional: it helps with forming a coherent sense of self and using past experiences to guide future behaviour (Bluck, 2003; Duff et al., 2024; Faul et al., 2024). Research shows that autobiographic memory provides guidance by allowing individuals to imagine themselves in the future based on personal memories that are similar (Faul et al., 2024). This so-called *directive* function of autobiographic memory is important for the theoretical understanding of event centrality, as both are related to meaning-making. How traumatic memories become central and why this is related to increased involuntary memories will be explained in the next paragraphs.

Predictors and Consequences of Event Centrality

Frequent Retrieval and Accessibility as Predictors of Event Centrality

The high centrality of traumatic memories is related to their *accessibility* (Berntsen & Rubin, 2007). Accessibility refers to the ease with which a memory is recalled, and it

increases when a memory is frequently retrieved and/or has distinct, emotional content (Rubin, 2011). Note that these three elements can occur independently or interact with each other to influence accessibility. As traumatic memories typically meet these conditions, they are likely to remain highly accessible (Berntsen & Rubin, 2007). According to Tversky & Kahneman (1973), people estimate the likelihood of an event occurring based on how accessible its memory is in autobiographic memory. This is referred to as the *availability heuristic*, which can be seen as a "shortcut" for people to make quick judgements and predictions for situations in their daily lives based on their past experiences. As a result, despite traumatic events being relatively rare, the high accessibility of traumatic memories can "trick" individuals who have experienced a trauma into overestimating the probability of such events occurring. In other words, the high accessibility of a traumatic memory makes the traumatic event a reference point for other experiences when perhaps it should not be one.

Highly accessible personal memories are often seen as anchors that help organize autobiographical knowledge (Berntsen & Rubin, 2007). They shape our life stories and play a role in stabilizing our self-concept by forming associative networks with typically less distinct memories. This is a functional and usually harmless process, but when a traumatic memory becomes a reference point, the consequences can be more severe. For instance, when a person's memory of a traumatic event is very accessible and starts acting as a central point of reference for interpreting other situations, they may start to see similarities between new, harmless situations and the previously experienced traumatic one (Berntsen et al., 2003; Berntsen & Rubin, 2007). This can happen even if the similarities are minor details, like a certain smell or sound, that happen to match parts of the traumatic memory. This process can also reshape one's life story and self-concept, as otherwise neutral parts of a person's life and identity risk now being seen through the lens of the trauma (Berntsen & Rubin, 2007).

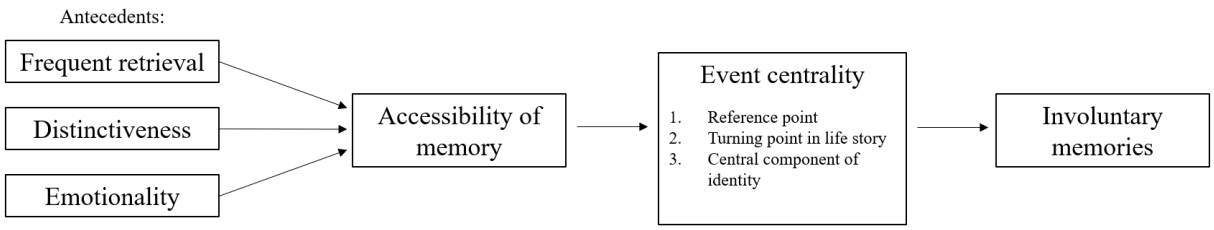
Involuntary Memories as a Consequence of High Event Centrality

The event centrality theory suggests that involuntary memories are a consequence of high event centrality of a memory (Berntsen & Rubin, 2006, 2007). Per definition, involuntary memories occur spontaneously and without a person's voluntary recall, but they do not arise completely out of the blue. The occurrence of involuntary memories is cue-driven, meaning that a certain stimulus – often from the environment – unwittingly reminds the person of a memory and can trigger its retrieval (Berntsen, 1996). These cues can be obvious and clear, but also very subtle and indirect. When a memory has high event centrality, it has become progressively more connected to other memories via the several links it has formed as a reference point in an associative network (Berntsen et al., 2003; Berntsen & Rubin, 2007). Each of these associated memories have their own set of cues from the environment that can trigger retrieval, and consequently also the retrieval of the central memory linked to them. The larger the number of memories linked to the central memory, the larger the number of potential cues from the environment that can activate the central memory. This can lead to an increase in involuntary recalls of the central memory.

To summarise the links between event centrality and the related variables, please see Figure 1 for a schematic model. Taken together, event centrality seems like a crucial link in the development and persistence of symptoms like involuntary memories, and warrants further investigation.

Figure 1.

The Proposed Theoretical Model of Event Centrality



Note. Antecedents occur independently or interact with each other to influence accessibility. Accessibility is heightened by a memory's 1) frequent retrieval, 2) distinctiveness, and 3)

emotionality. In turn, accessibility increases the centrality of the event in autobiographic memory, consisting of three facets: 1) it becomes a reference point for generating expectations, 2) it becomes a turning point in one's life story, and 3) it becomes a central component of one's identity. Heightened event centrality then leads to more involuntary memories.

Findings from Previous Research and Causal Pathways

Previous research has established a positive correlation between event centrality and post-traumatic stress symptoms such as involuntary memories. In their systematic review, Gehrt et al. (2018) found that avoidance, arousal, and especially re-experiencing (e.g. involuntary memories) all correlate with event centrality. Moreover, a few longitudinal studies found that event centrality predicts involuntary memories at a later time (Boals & Ruggero, 2016; Grau et al., 2021), yet others found it hard to determine the direction of influence between these variables (Johanßen et al., 2022). A different longitudinal study found evidence for the opposite direction: PTSD symptoms predicted event centrality over an 18-month follow-up period, but not vice versa (Stevens et al., 2022). Together, the existing literature illustrates that the pathways of the model as described in Figure 1 have not been strongly supported by empirical evidence. Variables could influence each other in all kinds of ways, involving feedback loops yet to be discovered, which calls for an experimental investigation of the event centrality model.

Experimental Evidence

To date only few studies have attempted to experimentally manipulate event centrality to assess its effect on involuntary memories, using varying methodological approaches. Three of these studies designed interventions to reduce PTSD symptoms by targeting event centrality through various interventions. One of them indeed found support that reducing event centrality leads to a decrease in PTSD symptoms (Boals & Murrell, 2016), but two other studies did not find this effect (Boals et al., 2015; Vermeulen et al., 2019). Please note that these studies focused on the broader symptom clusters of PTSD instead of specifically

involuntary memories. Still, the findings indicate that evidence for the theorised causal relationship seems mixed.

Noteworthy is that these studies based their methodologies on varying theoretical underpinnings. For instance, Vermeulen and colleagues (2019) targeted maladaptive cognitions that they argued were the key to event centrality by using a cognitive-bias-modification app. Alternatively, Lancaster and Erbes (2016) used a persuasive writing task as their manipulation, during which participants were instructed to convince others of the severity of the chosen event. They found short-term increases of event centrality after the persuasive writing task (Lancaster & Erbes, 2016). Their reasoning behind this effect was that the narrative process itself could change the meaning – and thus, centrality – of an experienced event, and that participants unintendedly convince themselves of the importance too (Lancaster & Erbes, 2016). Still, Berntsen and Rubin (2007) propose that the centrality of a memory is influenced by the specific characteristics of that memory, in particular its accessibility in autobiographic memory. Lancaster and Erbes (2016) briefly mention this effect as well, hypothesising that persuasively linking a memory to various other events in ones life during a writing task can make the memory more salient or accessible. However, they did not test this specific relationship directly in their experiment, therefore, their theorising could not be supported.

Though accessibility is argued to be a driving factor in the development of event centrality (Berntsen & Rubin, 2006), this effect currently lacks direct experimental support. Without such evidence, potentially important variables to target in PTSD interventions might remain unidentified. Furthermore, it is currently unclear whether involuntary memories are even caused by event centrality, or whether these variables are otherwise related. To address these gaps, this paper aims to develop a comprehensive theoretical and experimental framework for event centrality, exploring both the theorised antecedents and consequences.

The Current Study

The current study investigates how the frequent retrieval of a memory affects that memory's accessibility, event centrality, and the occurrence of involuntary memories. In the proposed model, frequent retrieval is one of the elements that is related to a memory's accessibility. I will be manipulating frequent retrieval, because this is the most straightforward strategy in an experimental setting compared to attempting to manipulate memory characteristics such as emotionality and distinctiveness. Moreover, it has been found that frequent retrieval is a strong correlate of event centrality (Pociunaite & Zimprich, 2023). The frequently retrieved memory will be a positive one, for two reasons. First, there is evidence that traumatic memories are not processed differently from other memories in autobiographical memory (Berntsen, 2001; Rubin et al., 2011), making the frequent retrieval of positive memories more ethical for participants. Second, it allows for exploration of how accessibility and event centrality of a positive memory influence the accessibility, event centrality, and involuntary memories of negative memories. Though preliminary, this could offer insight into potential intervention strategies.

Main Hypotheses

Compared to no retrieval, frequent retrieval of a memory leads to an increase in …

H1) … accessibility of that memory;

H2) … event centrality of that memory;

H3) … involuntary memories of that memory.

Explorative Hypotheses

H4) Increased accessibility of a memory is related to increased event centrality for that memory.

H5) Increased event centrality of a memory is related to an increase in involuntary memories of that memory one week follow-up.

H6) Increased accessibility of one memory is related to decreased accessibility of other memories (positive and negative).

H7) Increased accessibility of a positive memory is related to decreased event centrality of a negative memory.

Methods

Transparency

The study was preregistered (see OSF project; osf.io/grm64). There were a few deviations from this preregistration. First, the initial data collection phase did not result in the anticipated sample size, so a second round of data collection was introduced. In the second round, the instructions of the involuntary memories scale (IES-R, Weiss & Marmar, 1997) were slightly adapted to fit the study's design better (see Appendix A for the new instructions). Initially, the instructions did not consider the option of recalling a positive memory, which could have made participants interpret the items differently. As the new instructions might have caused discrepancies between the responses in round 1 and round 2, it was decided to split the data into two parts, from now on referred to as dataset 1 and dataset 2. Both datasets have the same structure. Unfortunately, the second round of data collection still did not yield a sufficient number of participants to reach the desired sample size, therefore, both studies are regarded and discussed as pilot studies.

There were also some deviations from the data analysis plan. First, additional preparations of both datasets had to be made due to unforeseen complications with the data structure. This is elaborated on later (see 'Data Analysis'). Second, the participants that should have been excluded based on a failed manipulation check were kept in the analysis, as exclusion would have left a too small sample size. Third, the assumptions that were violated were not accounted for in the data, as there were already quite a few issues with the sample and manipulation. In the original plan outliers that were three times the IQR were to be

removed. Then, the analyses would be performed twice: once with outliers and once without them, to see if there was a difference in results. If there was no difference in outcomes, the outliers would be kept in the dataset. A few outliers were identified, but the analysis was not conducted again after their removal. The results are likely not very meaningful after these deviations, but they are reported, interpreted, and discussed in order to meet the learning objectives of the master's thesis.

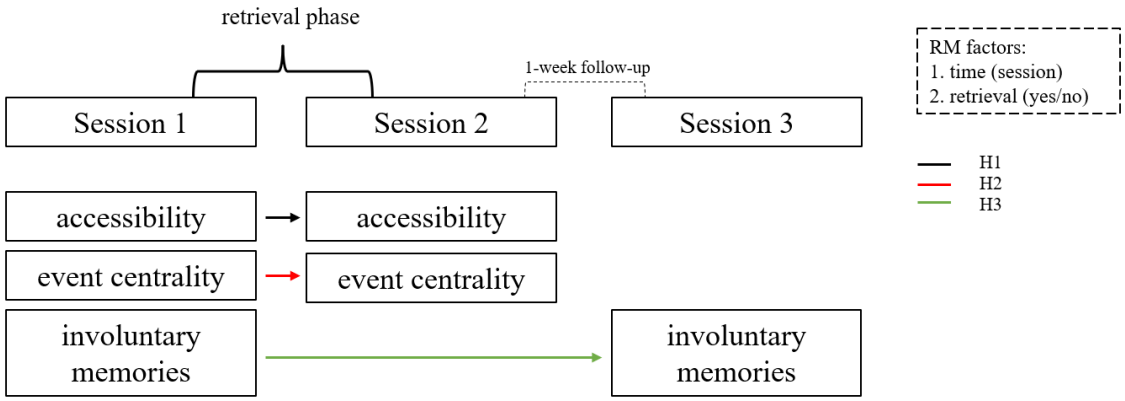
Design

The study has a 2x3 within-participants design, consisting of three lab sessions and a six-day experimental phase. The factors are 'retrieval' (yes/no), and 'time' with two levels depending on the hypothesis (see Figure 2). For each hypothesis, the effect of frequent retrieval on the respective dependent variable is assessed over time, comparing the variable at two time points (sessions). Hence, despite the set-up of the experiment, for the statistical analyses a 2x2 design is more applicable. The dependent variable for hypothesis 1 is accessibility, the dependent variable for hypothesis 2 is event centrality, and the dependent variable for hypothesis 3 is the extent of involuntary memories.

G*Power (Faul et al., 2007, 2009) was used to conduct an a-priori power analysis. For a repeated-measures ANOVA, a sample size of 88 participants was determined to detect an effect size of 0.25 with a power of 0.80 ($\alpha = 0.0167$). As the study employs a novel approach and there was limited literature to predict the effect size, a small effect size (Cohen's *d*) of 0.25 seemed like a reasonable, educated guess. We chose the most common value of 0.8 for the power, which means there is an 80% chance of correctly rejecting the null-hypothesis. The value of alpha was determined by dividing the standard value of 0.05 by the number of main hypotheses. This was decided to avoid questionable research practices, as three similar statistical tests could increase the chance of false positives.

Figure 2.

Schematic Overview of the Experimental Design and Variables



Note. The study has a 2x3 within-participant design, yet for the hypothesis-testing, a 2x2 within-participant design applies. For each hypothesis, the effect of frequent retrieval on the respective variable is assessed over time, comparing the variable at two time points (sessions).

The exploratory part of this study has a correlational and predominantly cross-sectional design. The operationalised dependent variable for hypothesis 4 is the event centrality score of the frequently retrieved memory during Session 2. For hypothesis 5, the dependent variable is the involuntary memories score of the frequently retrieved memory during Session 3. The dependent variable for hypothesis 6 is the averaged accessibility score of the non-retrieved memories during Session 2. Lastly, the dependent variable for hypothesis 7 is the averaged accessibility score of the non-retrieved memories during Session 2. For three out of four hypotheses (H4, H6, H7), the accessibility score of the frequently retrieved memory during Session 2 serves as the independent variable. For hypothesis 5, the event centrality score of the frequently retrieved memory during Session 2 is the independent variable. The scores of the respective variables from Session 1 are added to the model as covariates.

Sample

Participants were first-year Psychology students recruited through the SONA participant pool (https://www.sona-systems.com) of the University of Groningen ($N = 9$ in dataset 1; $N = 21$ in dataset 2). The mean age in dataset 1 was 19.78 ($SD = 1.79$), with a

majority of the participants being female (78%). In dataset 2, the mean age was 20.24 (*SD* = 2.32), with 71% of the participants being female. Participants had to be at least 18 years old and have sufficient knowledge of the English language to be eligible for the study. They were excluded when they presented with PTSD symptoms or had been diagnosed with another mental illness in the past six months, and/or were in active treatment by a certified therapist at the time of participation. In dataset 1, one participant was excluded after the screening and another participant dropped-out after Session 1. In dataset 2, no participants were excluded after the screening, but nine participants dropped-out during the study.

Materials

Screening Instruments. The 10-item Trauma Screening Questionnaire (TSQ; Brewin et al., 2002) was used to screen for PTSD symptoms. Items were answers with 'yes' (1) or 'no' (0). Participants with a score of 6 or higher were not eligible for the study and were excluded from participation. Reliability of this scale was low for both datasets (Cronbach's $\alpha = 0.29$ in dataset 1; Cronbach's $\alpha = 0.32$ in dataset 2). Since this was a screening instrument, note that the low reliability could have played a role in wrongful exclusion or inclusion of participants, as their scores might not consistently represent their actual state.

Content of memories. Participants had to write down their three most negative memories and three most positive memories of personal events, and link a keyword of their own choosing to each of the memories. The written memory content and keywords should not contain any identifying information (e.g. names of people, school name).

Event centrality. Event centrality was measured with the validated 7-item version of the Centrality of Events Scale (CES; Berntsen & Rubin, 2006). Items were answered on a 5-point Likert scale (1 = *totally disagree*, 5 = *totally agree*). An example of an item included in this scale is "*I feel that this event has become part of my identity*." Total scores range between

7 and 35. In dataset 1, reliability of the scale was good for all three sessions (Cronbach's α ranging from 0.88 to 0.92). In dataset 2, the reliability was comparable, but slightly lower for all three sessions (Cronbach's α ranging from 0.76 to 0.83).

Reference point. Additional to the CES, the reference point facet based on the availability heuristic was assessed with self-constructed items (1: "*How often does this event happen to other people in your environment?*", 2: "*What is the probability of something similar happening to you again in the future?*"). These items were answered on a scale from 0 ("*not at all*") to 100 ("*extremely*"). In dataset 1, reliability of these two items combined was okay for Session 1 (Cronbach's α = 0.70), low for Session 2 (Cronbach's α = 0.63), and good for Session 3 (Cronbach's α = 0.82). However, in dataset 2 the reliability was much lower overall (Cronbach's α ranging from .35 to .65), which means the two items had low internal consistency.

Memory characteristics. Memory characteristics were obtained to measure accessibility of the memory and simultaneously distract participants from the true purpose of the study. Included characteristics were accessibility, vividness, emotional intensity, valence, distinctiveness, and coherence. These were measured with a self-constructed single item per characteristic on a scale of 0 to 100 (0 = not at all, 100 = extremely; Accessibility: "*This memory came to mind easily*." Vividness: "*My memory for this event is vivid*." Emotional intensity: "*My emotions are intense concerning this event.*" Valence: "*The overall tone of my memory is positive*", "*The overall tone of my memory is negative.*" Distinctiveness: *"This memory stands out from other similar memories*." Coherence: *"The order of events in the memory is clear."* Since these were all single items, reliability could not be statistically assessed.

Involuntary memories. To assess the occurrence of involuntary recalls of the selected memories, the intrusion subscale of the validated Impact of Event Scale-Revised (IES-R;

Weiss & Marmar, 1997) was used. This subscale consists of 8 items that are answered on a scale ranging from 0 ("*not at all*") to 4 ("*extremely*"). An example of an item included in this subscale is "*Pictures about it popped into my mind*". Total scores range form 0 to 32. In dataset 2, the instructions of the scale were slightly adapted to fit the study's design (see Appendix A for the new instructions). Reliability of the scale was excellent in both datasets (Cronbach's $\alpha = 0.91$ for both sessions in dataset 1; Cronbach's $\alpha = .90$ in Session 1, Cronbach's $\alpha = .93$ in Session 3 in dataset 2).

Retrieval phase. For the retrieval phase of this study, we used the m-Path application developed by the KU Leuven (Mestdagh et al., 2023). This app sent out notifications at random times during the day with the keyword of the participant's randomly selected positive memory. Participants were then asked to retrieve the memory. Afterwards they indicated whether they did ("*How deeply did you engage with the memory*?" on a scale of 0-100) and how much time they spent recalling it in seconds ("*How much time (in seconds) did you spend thinking about the memory?*"). There were five notifications per day for six consecutive days.

Procedure

Participants signed up via the online SONA system for a three-session lab study with and at-home task, taking place at the University of Groningen, the Netherlands.

Session 1. At the start of Session 1, participants received brief instructions from the experimenter about the study, after which they signed an online informed consent form. All forms and questionnaires during the lab sessions were developed and administered via the online software program Qualtrics (Qualtrics, Provo, UT). When consent was given, the pre-screening began. If participants met the exclusion criteria, they were debriefed and asked to leave the lab. Participants who were not excluded, moved on to the second part of session 1. Here, participants were asked to write down their three most positive and three most negative autobiographical memories. They were instructed to leave out any identifying information

that could lead back to them, such as names of people and/or places. Each memory was marked by a keyword of the participant's own choice. The experimenter was available for questions and to monitor potential signs of distress. After the six memories had been written down, participants were asked to fill in questionnaires about the event centrality, general characteristics, and occurrence of involuntary memories for each of the six memories they provided. The questionnaires were presented to the participants in "packages" (i.e. they filled in all the questionnaires for one memory, then all the questionnaires for the next memory, etc.). In the final part of session 1, participants were guided to install the m-Path application and received instructions for the retrieval phase.

Retrieval phase. During the six-day retrieval phase, participants used the online application m-Path. During this phase, informally referred to as the at-home task, participants recalled one randomly selected positive memory whenever they get a notification from the application. This happened five times a day between 10 am and 8 pm, for six consecutive days). On the screen, the keyword they chose for the memory appeared and they were asked to take some time to recall it thoroughly. They indicated whether or not they completed the retrieval, how deeply they engaged with it, and how long they spent recalling it.

Session 2. During Session two, one week later, participants returned to the lab. They were asked to briefly summarise the memory linked to each keyword in one sentence, to check if they still recalled the same memories. The keywords were presented to the participants in a random order, typed in by the experimenter before the participant entered the lab. After this, they completed the questionnaire packages about the event centrality and memory characteristics of all six memories.

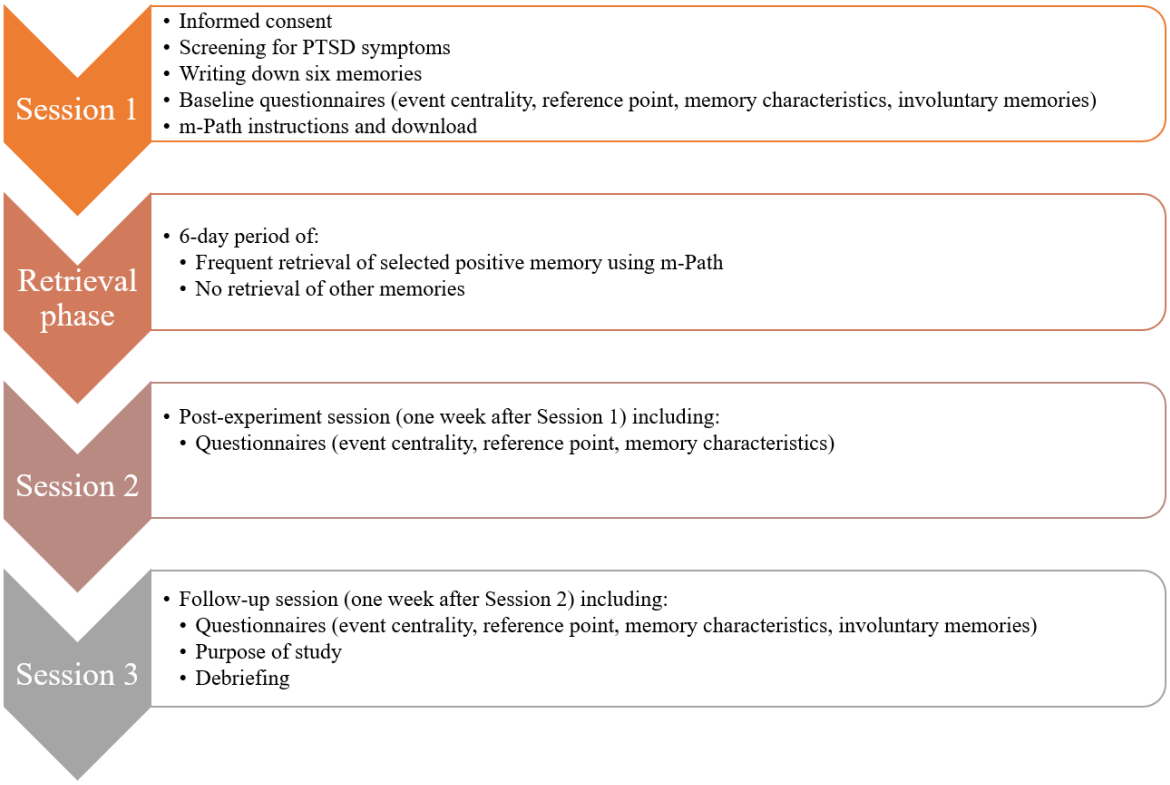
Session 3. Session 3 took place one week later. Participants were yet again instructed to briefly summarise the memory linked to each keyword in one sentence. Then, they completed the questionnaires packages about the event centrality, memory characteristics, and

the extent to which they had involuntary memories of the six memories in the past week. Finally, participants were asked about the purpose of the study, and a short debriefing followed. If participants had any comments or questions, they could write them down. Once data collection had completed, a more detailed debriefing was sent to all participants by email. This was to prevent participants from disclosing the purpose of the study to other potential participants.

See Figure 3 for a schematic overview of the procedure.

Figure 3.

Overview of Procedure of the Study per Session/Phase



Note. The study's full procedure takes three weeks.

Data Analysis

Data Preparation and Structuring

First, the data were checked for missingness. If a participant had dropped out at any point during the study, they were excluded from the analysis. Here, the manipulation was also

assessed by checking the response rate in m-Path for each participant. Originally, if participants missed more than 20% of the notification during the retrieval phase, they were to be excluded. However, as this limit appeared to be too constrictive in the current sample, other thresholds were explored (see 'Transparency').

Second, the data had to be recoded to be fit for analysis due to unforeseen complications with the data structure. In Session 1 participants each wrote down six personal memories (three negative and three positive) and provided a keyword for each memory. These keywords were linked to a questionnaire package, so the participant knew which memory to keep in mind while answering the questions. In Session 2 and 3, the keywords with each a questionnaire package were presented to them in a different, but predetermined, random order. In other words, responses from the first questionnaire package in Session 1 likely corresponded to a different memory than the responses from the first questionnaire package in Session 2 or Session 3. Unfortunately, when constructing the questionnaire in Qualtrics, this randomisation process was not taken into account for the variable labels. This meant that linking the responses from each questionnaire package back to their respective memory was a challenge, as 'memory number 3' could refer to a different memory in each session. Therefore, we manually recoded the data, such that each keyword was linked to the memory's condition ('frequently retrieved' or 'non-retrieved') and valence ('positive or negative'), making sure the responses matched the same memory for all three sessions. Due to time constraints, total scores per scale were computed and used, instead of recoding every separate item.

Third, reliability was assessed for the included measures, using Cronbach's alpha ($\geq$ 0.75 for good reliability). For efficiency, this was done for only the first reported memory, but for all sessions. Fourth, the reference point items were summed as a total score, to be able to use it as one variable. Additionally, the averaged score of each variable for the non-retrieved

memories were computed, in order to compare them to the frequently retrieved memory. This was done for 1) the two non-retrieved positive memories, 2) the three non-retrieved negative memories, and 3) all five non-retrieved memories. Finally, general descriptive statistics such as means and standard deviations were computed for exploration of the data. Moreover, bivariate correlations between the continuous variables were explored to gain insight into the relationships between the variables. Both cross-correlations as auto-correlations at the different timepoints were considered.

Main Analysis

For the main analysis, three separate repeated-measures ANOVAs were conducted – one to test each main hypothesis. See Figure 2 for a schematic overview of the variables and factors per RM-ANOVA. The data were first converted into a long format, so they were fit for RM-ANOVA analysis with condition ('retrieval') and time as separate within-subjects factors. Then the model was computed for each dependent variable, including main effects of retrieval and time, and the interaction effect. Effect sizes were assessed with partial eta-squared. Plots of the interaction effect were made to help with visualisation.

Assumptions for RM-MANOVA were checked. The first two assumptions were already met due to the nature of the design: continuous dependent variables and related groups. Normality of the dependent variable was assessed using the Shapiro-Wilk test of normality and inspecting Q-Q plots of the dependent variables. The assumption of sphericity did not apply for the current analysis, since only two measurement moments were compared. Finally, the data were checked for extreme values.

Exploratory Analysis

The exploratory hypotheses were tested with multiple regression analyses. The model was fitted using the respective variables for each hypothesis. Effect sizes were assessed with the value of f^2 and the adjusted R-squared. Finally, partial regression plots were computed for

the adjusted relationship in which the effects of the covariates were removed, to see if there were differences in the results.

Assumptions for multiple regression were also checked. These included linearity, independence of residuals, homoscedasticity, normality of residuals, and no multicollinearity. Linearity was assessed by inspecting scatterplots and using the Durbin-Watson test for linearity. Normality of the dependent variable was assessed using the Shapiro-Wilk test of normality and inspecting Q-Q plots of the dependent variables. Homoscedasticity was checked with the Breusch-Pagan test. Multicollinearity was checked with the Variance Inflation Factor (VIF), where VIF < 4 meant no multicollinearity.

Results

Missing Data and Manipulation Check

In dataset 1, one participant dropped out after Session 1 and was therefore excluded from data analysis. In dataset 2, nine participants dropped out during the study and were excluded from data analysis (see Table 1 for an overview of drop-out per session in dataset 2). Overall, of the 39 participants who completed the at-home retrieval task, 33 missed more than 20% of the notifications and thus failed the manipulation check. This left only three valid cases in both dataset 1 and dataset 2. Therefore, we left in all cases in both datasets for the sake of conducting the analyses with a slightly larger sample. 46% of the participants missed more than half of the notifications. In both datasets, none of the included cases had missing values throughout all three sessions.

Table 1.

Dropout Rate in Dataset 2 with Sample Size per Session

Study stage	***N***	**Drop-out percentage**	**Proportion of original sample**
Session 1	30	0%	100%
Session 2	26	13%	87%

Session 3	21	19%		70%

Note. N represents the sample size. Drop-out percentage represents the drop-out rate compared to the sample of the previous session.

Descriptive Statistics

The means and standard deviations of the variables for both retrieval conditions are summarised in Table 2 for dataset 1 and in Table 3 for dataset 2. The correlations between the main variables in dataset 1 and dataset 2 at the different measurement moments can be found in Appendix B (Table 1-6, respectively). Table 5 (dataset 1) and Table 6 (dataset 2) in the Appendix B display the correlations between event centrality and reference point.

Table 2.

Means and Standard Deviations of the Main Variables per Session in Dataset 1

	Session 1		**Session 2**		**Session 3**	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*
Accessibility FR	57.56	28.53	67.00	13.88	68.89	17.35
Accessibility NR	76.33	14.82	71.78	22.56	70.72	19.40
Event centrality FR	19.22	7.08	19.11	5.30	20.67	4.36
Event centrality NR	22.28	6.09	22.61	3.95	21.89	4.39
Involuntary memories FR	3.44	5.55	–	–	2.89	2.15
Involuntary memories NR	4.72	6.57	–	–	3.33	4.05
Reference point FR	100.20	51.60	116.22	59.28	100.90	59.54
Reference point NR	105.06	40.60	104.22	48.17	95.44	47.90

Note. FR refers to the frequently retrieved memory. NR refers to the averaged scores of the non-retrieved positive memories. Reference point refers the sum of the two reference point items. *M* and *SD* are used to represent mean and standard deviation.

Table 3

Means and Standard Deviations of the Main Variables per Session in Dataset 2

	Session 1		**Session 2**		**Session 3**	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*
Accessibility FR	78.19	20.43	78.14	21.32	76.89	17.91

Accessibility NR	75.38	16.49	73.93	18.42	74.3	17.36
Event centrality FR	22.76	6.66	22.86	4.96	22.19	6.31
Event centrality NR	22.36	5.57	21.93	6.72	21.17	6.72
Involuntary memories FR	6.90	7.23	–	–	6.90	8.02
Involuntary memories NR	4.45	4.11	–	–	4.62	5.66
Reference point FR	116.3	46.88	116.24	48.84	113.48	46.54
Reference point NR	104.12	44.34	107.29	39.98	101.83	41.22

Note. FR refers to the frequently retrieved memory. NR refers to the averaged scores of the non-retrieved positive memories. Reference point refers the sum of the two reference point items. *M* and *SD* are used to represent mean and standard deviation.

Main Analysis: Repeated Measures ANOVA

Assumptions Check

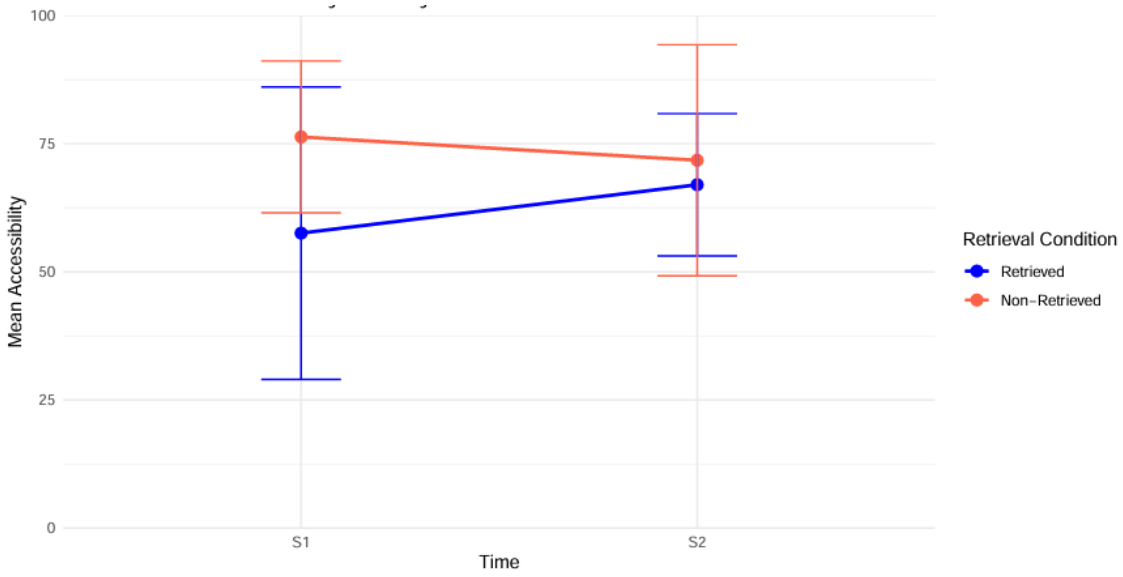
Assumptions for repeated-measures ANOVA have been assessed for all three hypotheses. In dataset 1, there were some violations. For the accessibility model (H1), the assumption of normality did not hold ($W = 0.92$, $p = 0.01$). The other assumptions did hold. For the event centrality model (H2), all assumptions applied. For the involuntary memories model (H3), the assumption for normality did not hold ($W = 0.80$, $p < .001$). Furthermore, there was one outlier detected that was more than 3 times the IQR. In dataset 2, there were similar violations. For the accessibility model (H1), there were two outliers detected that were more than 3 times the IQR. The other assumptions did hold. For the event centrality model (H2), there was one outlier. The other assumptions were okay. For the involuntary memories model (H3), the assumption for normality did not hold ($W = 0.92$, $p < .001$). Furthermore, three outliers were identified. However, since there were already multiple issues with the data (e.g. small sample size, failed manipulation check) and the current study serves as a pilot, it was decided not to remove the outliers and run the analysis twice for either dataset. However, due to these violations, the results presented here should be interpreted with caution

Hypothesis 1: Accessibility

First, an RM-ANOVA was a conducted to test whether frequent retrieval of a memory led to an increase in accessibility of that memory compared to no retrieval (hypothesis 1). There was no statistically significant interaction effect of retrieval and time for the accessibility score in both dataset 1 ($F(1, 24) = 1.23$, $p = .28$, $\eta_p^2 = .35$) and dataset 2 ($F(1, 60) = 0.05$, $p = .82$, $\eta_p^2 = <.001$). See Table 7 (dataset 1) and Table 8 (dataset 2) in Appendix C for a complete overview of the model estimates, including the main effects of retrieval and time. As presented in Table 2, in dataset 1 a small increase in the mean accessibility score was observed for the frequently retrieved memory, but not for the averaged non-retrieved positive memories. Table 3 shows that in dataset 2 barely any difference in the mean accessibility score was observed for either memory condition. See also Figure 4a and 4b for a visualisation of the change in mean accessibility score during Session 2 compared to Session 1.

Figure 4a.

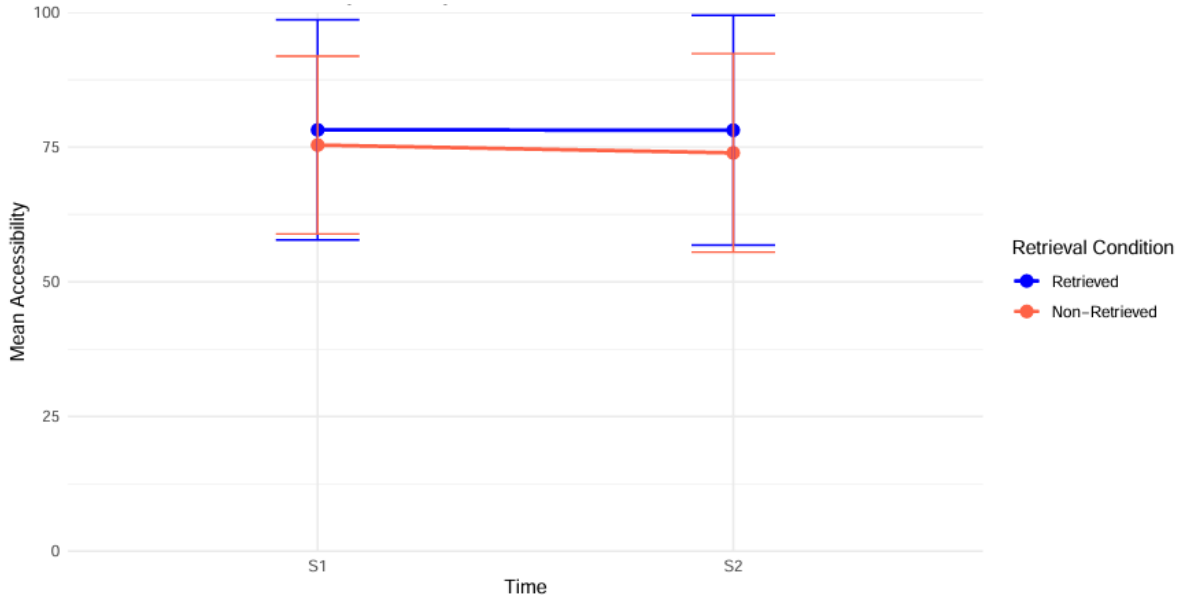
Change in Mean Accessibility Score Between Session 1 and Session 2 in Dataset 1



Note. S1 = Session 1, S2 = Session 2. The error bars represent one standard deviation.

Figure 4b.

Change in Mean Accessibility Score Between Session 1 and Session 2 in Dataset 1



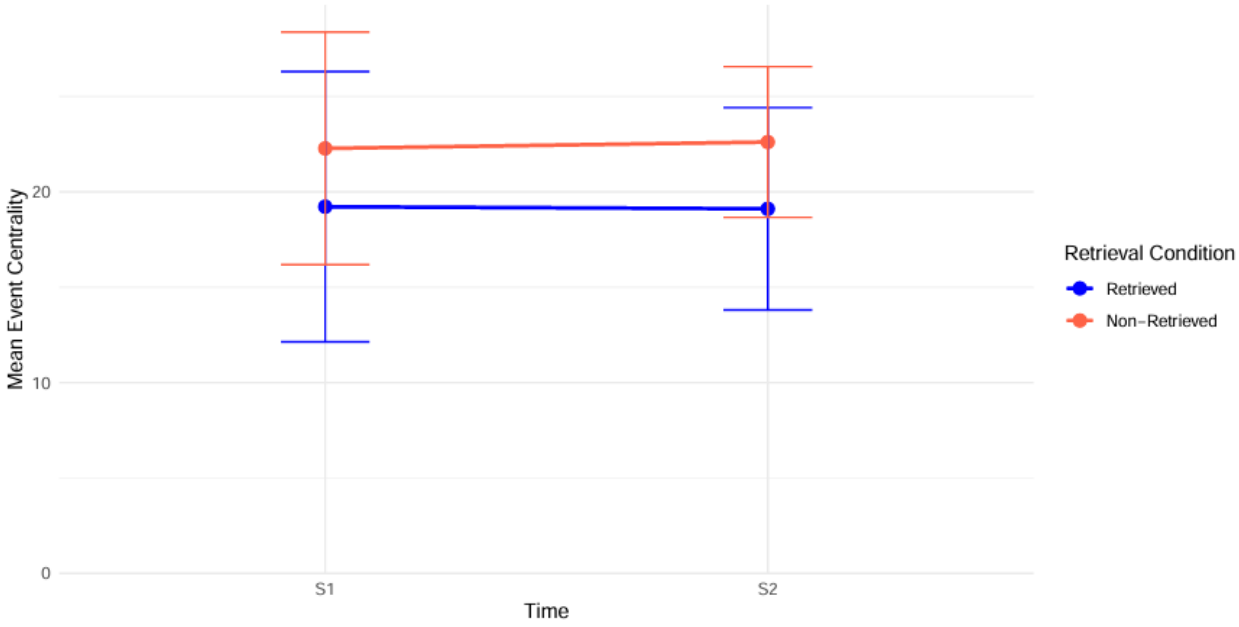
Note. S1 = Session 1, S2 = Session 2. The error bars represent one standard deviation.

Hypothesis 2: Event Centrality

Second, an RM-ANOVA was conducted to test whether frequent retrieval of a memory led to an increase in event centrality of that memory compared to no retrieval (hypothesis 2). There was no statistically significant interaction effect of retrieval and time for the accessibility score in both dataset 1 ($F(1, 24) = 0.02$, $p = .88$, $\eta_p^2 = .02$) and dataset 2 ($F(1, 60) = 0.07$, $p = .79$, $\eta_p^2 = <.001$). See Table 9 (dataset 1) and Table 10 (dataset 2) in Appendix C for a complete overview of the model estimates, including main effects. Referring back to Table 2, hardly any differences in the mean event centrality score were observed in dataset 1 for either the frequently retrieved memory or the averaged non-retrieved positive memories. Table 3 shows that the same applies to dataset 2. See also Figure 5a and 5b for a visualisation of the change in mean event centrality score between Session 1 and Session 2.

Figure 5a.

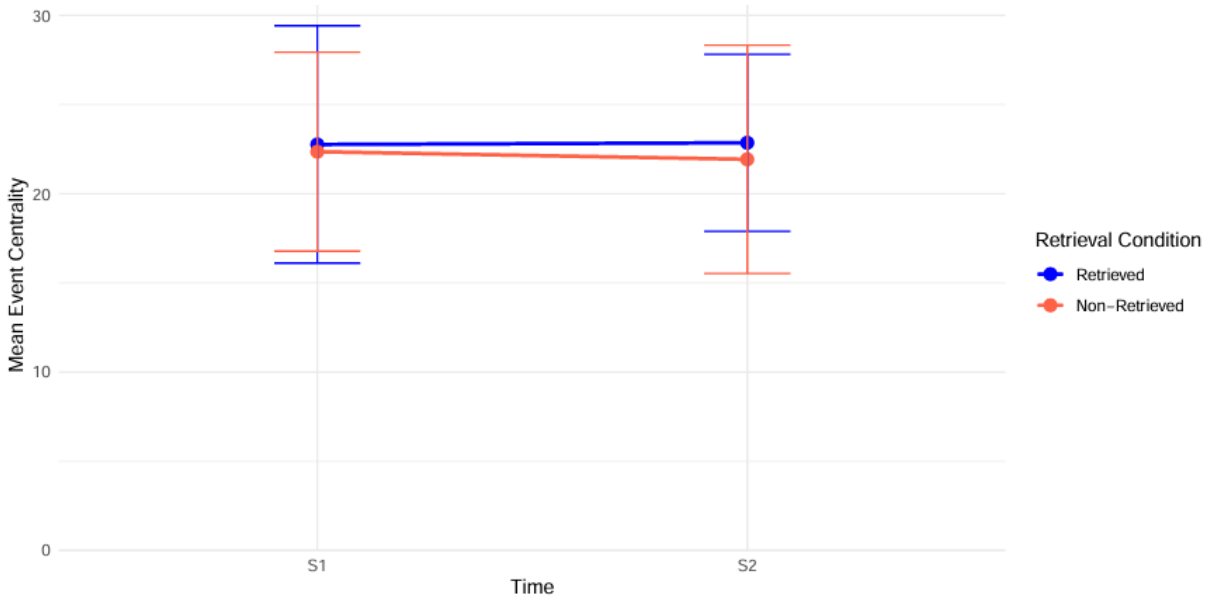
Change in Mean Event Centrality Score Between Session 1 and Session 2 in Dataset 1



Note. S1 = Session 1, S2 = Session 2. The error bars represent one standard deviation. Total scores range from 7 to 35.

Figure 5b.

Change in Mean Event Centrality Score Between Session 1 and Session 2 in Dataset 2



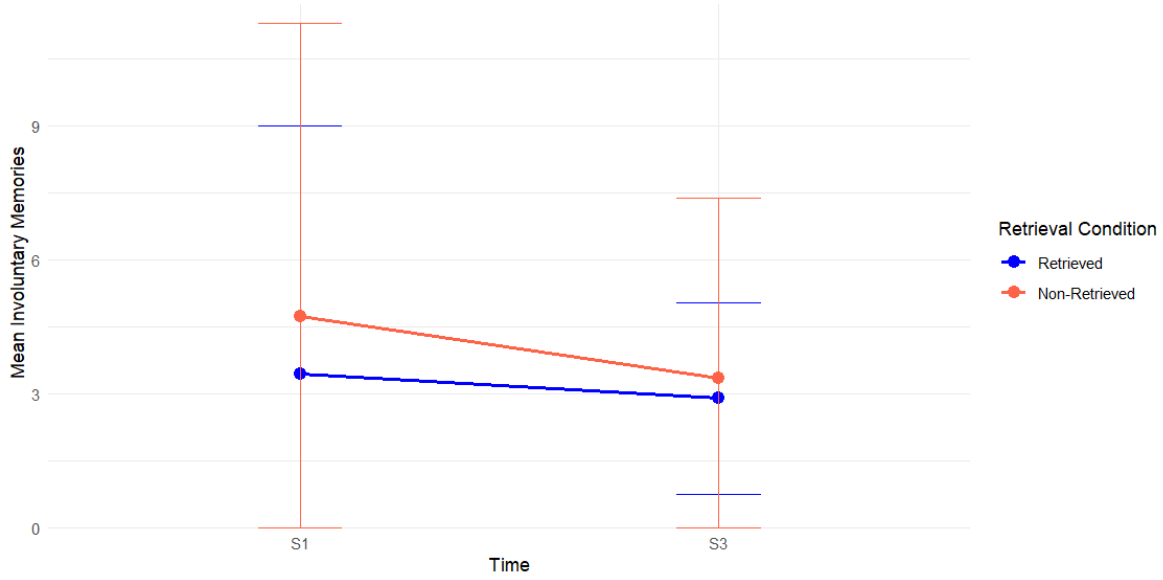
Note. S1 = Session 1, S2 = Session 2. The error bars represent one standard deviation. Total scores range from 7 to 35.

Hypothesis 3: Involuntary Memories

A final RM-ANOVA was a conducted to test whether frequent retrieval of a memory led to an increase in the extent of involuntary memories for that memory compared to no retrieval (hypothesis 3). Again, there was no statistically significant interaction effect of retrieval and time for the involuntary memories score in both dataset 1 ($F(1, 24) = 0.10$, $p = 0.75$, $\eta_p^2 = .02$) and dataset 2 ($F(1, 60) = 0.01$, $p = 0.94$, $\eta_p^2 = <.001$). See Table 11 (dataset 1) and Table 12 (dataset 2) in Appendix C for a complete overview of the model estimates. Referring back to Table 2, the mean involuntary memories score in dataset 1 seemed to slightly decrease between Session 1 and Session 3 for both memory conditions. In dataset 2, the mean involuntary memories scores barely differed from each other over time, for both memory conditions (see Table 3). See also Figure 6a and 6b for a visualisation of the change in mean involuntary memories score between Session 1 and Session 3.

Figure 6a.

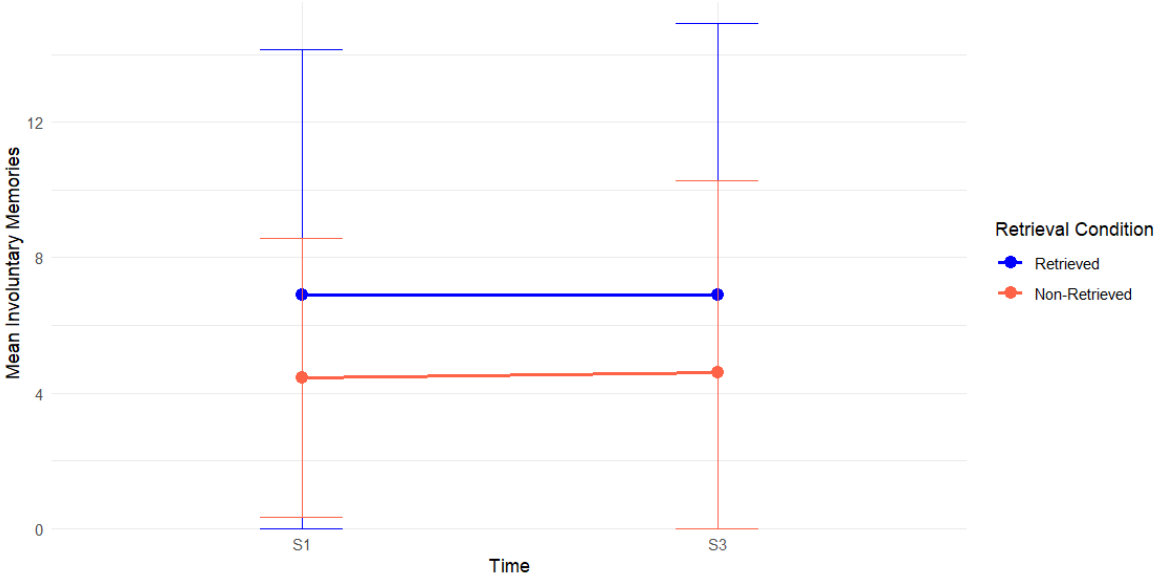
Change in Mean Involuntary Memories Score Between Session 1 and Session 3 in Dataset 1



Note. S1 = Session 1, S2 = Session 2. The error bars represent one standard deviation.

Figure 6b.

Change in Mean Involuntary Memories Score Between Session 1 and Session 3 in Dataset 2



Note. S1 = Session 1, S2 = Session 2. The error bars represent one standard deviation.

Exploratory Analyses

Assumption Check

The assumptions for multiple linear regression were assessed for the exploratory hypotheses. In dataset 1, there were a few violations. For the model of hypothesis 4, the assumption of normality did not hold ($W = 0.82$, $p = .04$) and linearity also seemed slightly violated. For the model of hypothesis 5, all assumptions held. For the model of hypothesis 6, the assumption of linearity also seemed slightly violated due to an outlier. For the model of hypothesis 7, most of the assumptions held, though linearity seemed slightly violated. In dataset 2, similar violations were observed. For the model of hypothesis 4, only the assumption of linearity seemed slightly violated. For the model of hypothesis 5, the assumption linearity and normality ($W = 0.82$, $p = .001$) were violated. For the model of hypothesis 6, the assumption of linearity also seemed slightly violated. For the model of hypothesis 7, all assumptions held except for normality ($W = 0.90$, $p = .04$). Because of these violations, the results should be interpreted with caution.

Hypothesis 4

To test the exploratory hypothesis that increased accessibility of a memory leads to increased event centrality for that same memory (H4), a multiple linear regression model was estimated. See Table 13 in Appendix D for an overview of the complete model, including the covariates. The accessibility score of the frequently retrieved memory during Session 2 was not a statistically significant predictor for the event centrality score of the frequently retrieved memory at Session 2 (b = -0.02, t = -0.16, p = .88). A similar effect was found in dataset 2 (b = 0.01, t = 0.27, p = .79). See Table 14 in Appendix D for an overview of the complete model from dataset 2, including the estimates for the accessibility and event centrality score of the frequently retrieved memory at Session 1.

Hypothesis 5

Next, the exploratory hypothesis that increased event centrality of a memory leads to an increase in involuntary memories of that memory one week follow-up (H5) was tested. In dataset 1, the event centrality score of the frequently retrieved memory during Session 2 was not a statistically significant predictor for the involuntary memories score of the frequently retrieved memory during Session 3 (b = -0.14, t = -0.70, p = 0.52). This was also the case in dataset 2 (b = -0.17, t = -0.36, p = 0.73). The potential effects of event centrality and involuntary memories of the frequently retrieved memory during Session 1 were controlled for in the analysis, but there were no statistically significant predictors in either dataset. See Table 15 (dataset 1) and Table 16 (dataset 2) in Appendix D for an summary of the estimated parameters in the multiple linear regression model.

Hypothesis 6

Then, the exploratory hypothesis that increasing accessibility of one memory decreases accessibility of other memories (positive and negative) (H6) was tested. The accessibility score of the frequently retrieved memory during Session 2 was not a statistically significant predictor of the averaged accessibility score of the non-retrieved memories during

Session 2 in both dataset 1 (b = 0.49, t = 1.43, p = .21) and dataset 2 (b = 0.25, t = 1.89, p = .08). See Table 17 (dataset 1) and Table 18 (dataset 2) in Appendix D for an overview of the estimates in the multiple linear regression model, including the covariates.

Hypothesis 7

Finally, another multiple linear regression analysis was conducted to test the exploratory hypothesis that increasing accessibility of a positive memory decreases event centrality of a negative memory (H7). The accessibility score of the frequently retrieved positive memory during Session 2 was not a statistically significant predictor of the averaged event centrality score of the non-retrieved negative memories during Session 2 (b = 0.06, t = 0.66, p = .54). This was also the case in dataset 2 (b = -0.01, t = -0.25, p = .54). See Table 19 (dataset 1) and Table 20 (dataset 2) in Appendix D for a complete overview of the model estimates, including the covariates.

Discussion

This study aimed to investigate how the frequent retrieval of a memory affects that memory's accessibility, event centrality, and the occurrence of involuntary memories. Considering the pilot nature of the design and the unanticipated small sample size in both datasets, the results of this study can only be interpreted as inconclusive. The results are discussed primarily to meet the learning goals of the master's thesis rather than draw concrete conclusions. Contrary to expectations, the findings showed no indication that frequent retrieval led to a statistically significant increase of the memory's accessibility (H1) or event centrality (H2) during Session 2 compared to Session 1. Moreover, there was no indication that frequent retrieval of a memory led to a statistically significant increase in the occurrence of involuntary memories of that memory during Session 3 compared to Session 1 (H3). Overall, the effect sizes observed in this study were extremely small, with large confidence

intervals, leaving much uncertainty. The exploratory hypotheses to examine the relationships between accessibility, event centrality, and involuntary memories were tested as well, taking into account the negative memories. However, none of the explored effects were found statistically significant in the current study.

Interpreting the Findings in Two Scenarios

There are two possible scenarios in which the nonsignificant and small effect size estimates of the anticipated effects can be interpreted. The first scenario is that the findings are potentially false negatives. Given the a-priori power analysis, the desired sample size to confidently estimate the true effect sizes was not reached. This means that this study was likely underpowered. In other words, as the parameters involved in the power analysis all relate to each other, the chance of false negatives is larger when the sample is small. This is especially likely when the effect is small as well, since it is harder to detect the little difference between conditions confidently with only a few scores to compare. Moreover, not all of the model assumptions were met for the statistical analyses, therefore, the results should be interpreted with extra caution. In this scenario, the evidence is interpreted as inconclusive.

However, for the second scenario, let's assume that power is not an issue and the small effects sizes would be found again in replications with the desired sample size. In this case, the statistical nonsignificant findings are not entirely in line with the literature. Previous research suggests that frequent retrieval, accessibility, event centrality, and involuntary retrievals of a memory all positively relate to each other (Berntsen & Rubin, 2008; Gehrt et al., 2018; Rubin et al., 2011). At the same time, experimental studies that tried to change event centrality yielded mixed evidence (e.g. Boals et al., 2015; Boals & Murrell, 2016; Vermeulen et al., 2019). This indicates that there was not a very strong foundation for the causal effects proposed in this study from the start, and the small effect sizes found here are hard to compare to previously estimated effect sizes.

Making Sense of the Null Results

Building on scenario 2, several explanations for the nonsignificant findings can be found. First of all, the hypothesized effects were based on a synthesis of evidence from the existing literature, which had some key differences in design and measures. Put differently, frequent (voluntary) retrieval and accessibility had not been studied in direct relation to event centrality, making comparison to earlier studies more difficult. Experimental studies that managed to successfully manipulate event centrality seemed to target a different facet of the construct. For example, Boals and Murrell (2016) reduced event centrality by broadening participants' self-concept through acceptance- and commitment therapy, which focuses more on the identity-facet of event centrality. Yet, research suggests that frequent retrieval of a memory (i.e., the manipulation in the current study) predominantly affects the reference-point-facet of event centrality (Rubin et al., 2011).

Another difference from previous research is that the majority of studies focused on the event centrality of traumatic or highly negative memories. Though there is evidence that traumatic memories do not differ from ordinary memories in how they are processed or retrieved (Rubin et al., 2011), other evidence suggests that negative events are more likely to be associated with vivid recollections than positive ones (Kensinger & Ford, 2020), and vividness is strongly correlated with event centrality (Gehrt et al., 2018).Therefore, the decision to frequently retrieve a positive memory in the current study might have resulted in a less strong manipulation than if it were a negative one.

Moreover, adherence during the retrieval phase was low, indicating that the manipulation was likely not very effective in both datasets. Nearly all of the participants exceeded the initial cut-off score for exclusion from data analysis by

missing too many notification from m-Path. This means that the frequently retrieved memory was not as frequently retrieved as anticipated, and the failed manipulation could play a serious role in the study's outcome. In addition, the six-day period with five notifications per day was chosen quite arbitrarily. Even if participants completed the retrieval phase with a 100 percent response rate, they would have retrieved the memory 30 times over a span of six days. This might still be too low a frequency or timespan to see an increase in accessibility, event centrality, and/or the extent of involuntary memories.

Related to effectiveness of the retrieval phase is that the three-week period may be too short to experience and measure substantial changes in event centrality. The potential, delayed change in involuntary memories after the experiment was accounted for by adding a one-week follow-up session to the design, but this timeframe is still quite short. Moreover, in this study participants were not asked how often they actively thought about the manipulated memory apart from the m-Path notifications. Likewise, there is no data on how often participants actively recalled the *other* five memories they had to answer questionnaires about. Therefore, it is unknown whether the other memories were recalled more often as well, for example through association with the manipulated memory.

Methodological Implications and Evaluation

The design of this study was newly developed and therefore, there are some methodological implications to inform future research in this field. An early challenge was reaching the desired sample size. The number of sessions and an at-home task might have been too much compared to the incentive participants received (a portion of participation credits necessary to pass a course). At the time of data collection for Study 2, recruitment was less of a problem. This might be due to the slightly increased incentive for participation after Study 1. Overall, drop-out rate was manageable. Still, repeating the same questionnaires for six memories three times can become monotonous after a while, and motivation may decrease

both within and between sessions. Therefore, it is important to recruit a bigger sample at the start of data collection, to end up with the desired sample size.

Regarding the manipulation, the lack of compliance during the retrieval phase might also be attributable to insufficient incentive. A recent meta-analysis on compliance in ecological momentary assessment (EMA) found that monetary incentives are the strongest predictor for completing the daily assessments (Wrzus et al., 2022). Contingent incentives (i.e. receiving the incentive when predetermined criteria are met during participation) were negatively related to compliance (Wrzus et al., 2022). This seems a relevant point for the current study, in which participants received participation credits at various stages of the experiment – nearly half of the credits already granted after the first session before the retrieval phase had even started. Moreover, participants might have felt less motivated to respond to all the notifications, because they would receive the credits anyway. A possible solution is that the incentive should only be granted at a later stage, or that it increases when participants have completed (most of) the retrievals. Furthermore, the meta-analysis indicated that the total number of assessments, assessment days, and assessments per day did not significantly predict compliance (Wrzus et al., 2022). For this study's experiment, this means that increasing the number of notifications for even more frequent retrievals should not harm study compliance per se, as long as there is an appropriate incentive to match the participation burden.

The repetitive nature of the questionnaire packages should also be taken into account. This might have influenced the accuracy of participants' responses over time. Presenting the memory keywords in a random order each session was meant to minimize the anticipated risk of order effects, yet it cannot be completely avoided. To decrease the number of questionnaires, the chosen number of six autobiographical

memories that participants had to recall could be brought down to four. At least two positive memories were necessary for the within-subjects design of this study. Initially, the idea was to collect multiple memories to make the comparison less obvious, yet reducing participation burden might outweigh the participant blinding. Another solution to reduce the number of questionnaires is to switch to a between-participant design, where participants are either placed in the frequent retrieval condition or the no-retrieval condition, and they each recall one positive and one negative memory at the start.

Finally, it was hard to completely blind participants from the purpose of the study. They might have guessed something should change regarding the manipulated memory, compared to the others. This could potentially lead to desirability bias. The extra items about memory characteristics were added to the questionnaires partly to make the variables of interest less obvious, but this might not have been effective.

Theoretical implications

Considering the methodological implications and limitations of this study, the theoretical model of event centrality can be neither supported or challenged by the evidence. Still, it could be possible that frequent retrieval is not a very salient variable contributing to event centrality and involuntary memories. Another possibility is that the direction of influence in the model is different in reality, or that there are other variables at play that were not included in the model. Replications would be necessary to confirm or disconfirm the findings, and with it the theoretical model.

Future Directions

After carefully evaluating this study's findings and methodology, it becomes clear that the methodological approach to investigating the causal mechanisms surrounding event centrality can be improved. Other researchers could use the lessons learned in the current study to build upon when designing their own methodology. To begin with, the limitations of

the current study could be improved by increasing the time between sessions and increasing the intensity of the retrieval phase. The frequency and duration of the retrievals should be experimented with to optimize a successful manipulation. Other incentives should be explored, for instance monetary rewards, taking into account the requirements for a successful manipulation. Equally important – once the approach is finetuned, the study could be repeated with a bigger, more diverse sample size. Finally, in light of the manipulation of the current study, more research is necessary on the importance of memory valence in relation to event centrality. If the theoretical model only works for negative memories, this design would not be suitable, for it would be unethical to attempt to increase the event centrality of highly negative memories. In this case, other approaches should be explored, perhaps in reducing event centrality.

Conclusion

This study introduced a new methodological approach to investigate exactly how frequent retrieval is related to event centrality, memory accessibility and the occurrence of involuntary memories. The event centrality theory first launched by Berntsen and Rubin (2006) present a framework on traumatic memories and PTSD symptoms that shows promising findings in correlational research. Still, there is barely any direct experimental evidence that tests the model. The current study attempted to validate the theory with an experimental design, yet the methodological approach is still in its infancy. Currently, the evidence found in this study can neither support nor contradict the theoretical model. Nevertheless, this study paves the way for future researchers to finetune a experimental approach to investigate event centrality. With sound methodologies, we can ultimately gain more knowledge on the mechanisms of traumatic memories in autobiographic memory, and how to effectively target those mechanisms to decrease psychological distress.

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Appendix A

Original instructions of the IES-R (Weiss & Marmar, 1997), used in Study 1:

"*Below is a list of difficulties people sometimes have after stressful life events. Please read each item, and then indicate how distressing each difficulty has been for you DURING THE PAST SEVEN DAYS with respect to [KEYWORD]. How much were you distressed or bothered by these difficulties?*"

Adapted instructions for the IES-R (Weiss & Marmar, 1997), used in Study 2:

"*Below is a list of experiences people may encounter after personal life events. Please read each item and indicate to what extent each has affected you during the past seven days with respect to [KEYWORD]. How much have you been affected or impacted by these experiences?*"

Appendix B

Table 1

Correlations with Confidence Intervals Between the Main Variables for the Frequently Retrieved Memory Dataset 1

Variable	1	2	3	4	5	6	7
1. Accessibility S1							
2. Accessibility S2	.36 [-.40, .83]						
3. Accessibility S3	.36 [-.40, .83]	.69* [.04, .93]					
4. Event Centrality S1	.33 [-.43, .82]	-.01 [-.67, .66]	.48 [-.27, .87]				
5. Event Centrality S2	-.41 [-.85, .34]	-.28 [-.80, .47]	-.10 [-.72, .60]	.52 [-.22, .88]			
6. Event Centrality S3	.36 [-.40, .83]	-.23 [-.77, .51]	.32 [-.44, .81]	.84** [.40, .97]	.53 [-.21, .88]		
7. Involuntary Memories S1	.41 [-.35, .84]	-.15 [-.74, .57]	.26 [-.49, .79]	.49 [-.26, .87]	-.21 [-.77, .53]	.38 [-.38, .84]	
8. Involuntary Memories S3	.34 [-.42, .82]	.24 [-.51, .78]	.57 [-.15, .90]	.62 [-.08, .91]	.09 [-.61, .71]	.41 [-.35, .84]	.43 [-.32, .85]

Note. $N = 9$. Each variable refers to the total score for the frequently retrieved memory. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.

Table 2.

Correlations with Confidence Intervals Between the Main Variables for the Frequently Retrieved Memory in Dataset 2

Variable	1	2	3	4	5	6	7
1. Accessibility S1							
2. Accessibility S2	.77** [.51, .90]						
3. Accessibility S3	.81** [.58, .92]	.74** [.46, .89]					
4. Event Centrality S1	.10 [-.35, .51]	.23 [-.22, .60]	.07 [-.37, .49]				
5. Event Centrality S2	.33 [-.12, .67]	.39 [-.05, .70]	.39 [-.05, .70]	.76** [.49, .90]			
6. Event Centrality S3	.07 [-.38, .48]	.24 [-.22, .61]	.26 [-.19, .62]	.72** [.42, .88]	.84** [.64, .93]		
7. Involuntary Memories S1	.23 [-.23, .60]	.20 [-.26, .58]	.14 [-.31, .54]	.27 [-.19, .63]	.27 [-.19, .63]	.14 [-.31, .54]	
8. Involuntary Memories S3	-.01 [-.44, .42]	.16 [-.29, .56]	.04 [-.40, .46]	.32 [-.13, .66]	.23 [-.22, .60]	.28 [-.17, .64]	.58** [.19, .81]

Note. $N = 21$. Each variable refers to the total score for the frequently retrieved memory. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.

Table 3.

Correlations with Confidence Intervals Between the Main Variables for the Averaged Non-Retrieved Positive Memories Dataset 1

Variable	1	2	3	4	5	6	7
1. Accessibility S1							
2. Accessibility S2	.35 [-.41, .82]						
3. Accessibility S3	.59 [-.12, .90]	.69* [.04, .93]					
4. Event Centrality S1	.53 [-.21, .88]	-.01 [-.67, .66]	.54 [-.19, .89]				
5. Event Centrality S2	.35 [-.41, .82]	.32 [-.44, .81]	.37 [-.39, .83]	.56 [-.17, .89]			
6. Event Centrality S3	.39 [-.37, .84]	.09 [-.61, .71]	.64 [-.05, .91]	.96** [.81, .99]	.60 [-.10, .91]		
7. Involuntary Memories S1	.58 [-.13, .90]	.45 [-.31, .86]	.51 [-.24, .88]	.73* [.12, .94]	.62 [-.08, .91]	.68* [.02, .92]	
8. Involuntary Memories S3	.27 [-.48, .79]	.32 [-.44, .81]	.39 [-.37, .84]	.71* [.08, .93]	.61 [-.09, .91]	.73* [.12, .94]	.87** [.48, .97]

Note. $N = 9$. The variables refer to the averaged total score for the non-retrieved positive memories. Values in square brackets indicate the 95% confidence interval.* indicates $p < .05$. ** indicates $p < .01$.

Table 4.

Correlations with Confidence Intervals Between the Main Variables for the Averaged Non-Retrieved Positive Memories in Dataset 2

Variable	1	2	3	4	5	6	7
1. Accessibility S1							
2. Accessibility S2	.77** [.51, .90]						
3. Accessibility S3	.68** [.36, .86]	.84** [.63, .93]					
4. Event Centrality S1	.54* [.14, .79]	.36 [-.08, .69]	.21 [-.24, .59]				
5. Event Centrality S2	.38 [-.07, .70]	.39 [-.04, .71]	.33 [-.12, .67]	.80** [.57, .92]			
6. Event Centrality S3	.33 [-.12, .67]	.34 [-.11, .67]	.28 [-.18, .63]	.83** [.63, .93]	.95** [.88, .98]		
7. Involuntary Memories S1	.24 [-.21, .61]	.16 [-.29, .56]	.30 [-.16, .64]	.44* [.01, .73]	.50* [.08, .76]	.44* [.01, .73]	
8. Involuntary Memories S3	.26 [-.20, .62]	.28 [-.17, .64]	.31 [-.15, .65]	.22 [-.23, .60]	.26 [-.20, .62]	.20 [-.25, .58]	.70** [.39, .87]

Note. $N = 21$. The variables refer to the averaged total score for the non-retrieved positive memories. Values in square brackets indicate the 95% confidence interval.* indicates $p < .05$. ** indicates $p < .01$.

Table 5.

Correlations with Confidence Intervals Between Event Centrality and Reference Point for the Frequently Retrieved Memory Dataset 1

Variable	1	2	3	4	5
1. Event Centrality S1					
2. Reference Point S1	.14 [-.58, .73]				
3. Event Centrality S2	.52 [-.22, .88]	.48 [-.27, .87]			
4. Reference Point S2	-.07 [-.70, .62]	.92** [.64, .98]	.29 [-.46, .80]		
5. Event Centrality S3	.84** [.40, .97]	.24 [-.50, .78]	.53 [-.21, .88]	.18 [-.55, .75]	
6. Reference Point S3	.22 [-.52, .77]	.98** [.88, .99]	.57 [-.15, .90]	.89** [.57, .98]	.36 [-.40, .83]

Note. $N = 9$. Each variable refers to the total score for the frequently retrieved memory. *Reference Point S1* = the mean of the two reference point items during Session 1, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.

Table 6.

Correlations with Confidence Intervals Between Event Centrality and Reference Point for the Frequently Retrieved Memory in Dataset 2

Variable	1	2	3	4	5
1. Event Centrality S1					
2. Reference Point S1	-.44* [-.73, -.01]				
3. Event Centrality S2	.76** [.49, .90]	-.42 [-.72, .02]			
4. Reference Point S2	-.34 [-.68, .10]	.84** [.63, .93]	-.42 [-.72, .02]		
5. Event Centrality S3	.72** [.42, .88]	-.30 [-.65, .15]	.84** [.64, .93]	-.26 [-.62, .19]	
6. Reference Point S3	-.42 [-.72, .02]	.59** [.21, .81]	-.45* [-.74, -.03]	.81** [.59, .92]	-.33 [-.67, .12]

Note. $N = 21$. Each variable refers to the total score for the frequently retrieved memory. *Reference Point S1* = the mean of the two reference point items during Session 1, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. * indicates $p < .05$. ** indicates $p < .01$.

Appendix C

Table 7.

Repeated Measures ANOVA Estimates from Dataset 1 with Factors Retrieval and Time and with Accessibility as Dependent Variable

	Model 1					
	Model coefficients					Effect size
	F	*SE*	*df1*	*df2*	*p*	η_p^2
Within-subjects effects						
Retrieval	4.45	8.89	1	24	.05	.25
Time	1.12	8.89	1	24	.30	.01
Retrieval × Time	1.23	12.57	1	24	.28	.35

Note. $N = 9$. Retrieval = frequently retrieved memory vs. averaged non-retrieved positive memories. Time = Session 1 vs. Session 2. The dependent variable is the accessibility score.

Table 8.

Repeated Measures ANOVA Estimates from Dataset 2 with Factors Retrieval and Time and with Accessibility as Dependent Variable

	Model 1					
	Model coefficients					Effect size
	F	*SE*	*df1*	*df2*	*p*	η_p^2
Within-subjects effects						
Retrieval	0.44	4.24	1	60	.51	.03
Time	<0.001	4.24	1	60	.99	<.001
Retrieval × Time	0.05	6.00	1	60	.82	<.001

Note. $N = 21$. Retrieval = frequently retrieved memory vs. averaged non-retrieved positive memories. Time = Session 1 vs. Session 2. The dependent variable is the accessibility score.

Table 9.

Repeated Measures ANOVA Estimates from Dataset 1 with Factors Retrieval and Time and with Event Centrality as Dependent Variable

	Model 2					
	Model coefficients					Effect size
	F	*SE*	*df1*	*df2*	*p*	η_p^2
Within-subjects effects						
Retrieval	2.25	2.03	1	24	.15	.34
Time	0.003	2.03	1	24	.96	<.001
Retrieval × Time	0.02	2.87	1	24	.88	.02

Note. N = 9. Retrieval = frequently retrieved memory vs. averaged non-retrieved positive memories. Time = Session 1 vs. Session 2. The dependent variable is the event centrality score.

Table 10.

Repeated Measures ANOVA Estimates from Dataset 2 with Factors Retrieval and Time and with Event Centrality as Dependent Variable

	Model 2					
	Model coefficients					Effect size
	F	*SE*	*df1*	*df2*	*p*	η_p^2
Within-subjects effects						
Retrieval	0.09	1.30	1	60	.77	.01
Time	0.005	1.30	1	60	.94	<.001
Retrieval × Time	0.07	1.92	1	60	.79	<.001

Note. N = 21. Retrieval = frequently retrieved memory vs. averaged non-retrieved positive memories. Time = Session 1 vs. Session 2. The dependent variable is the event centrality score.

Table 11.

Repeated Measures ANOVA Estimates from Dataset 1 with Factors Retrieval and Time and with Involuntary Memories as Dependent Variable

	Model 3					
	Model coefficients					Effect size
	F	*SE*	*df1*	*df2*	*p*	η_p^2
Within-subjects effects						
Retrieval	0.48	1.85	1	24	.50	.03
Time	0.59	1.85	1	24	.77	.10
Retrieval × Time	0.10	2.61	1	24	.75	.02

Note. N = 9. Retrieval = frequently retrieved memory vs. averaged non-retrieved positive memories. Time = Session 1 vs. Session 3. The dependent variable is the involuntary memories score.

Table 12.

Repeated Measures ANOVA Estimates from Dataset 2 with Factors Retrieval and Time and with Involuntary Memories as Dependent Variable

	Model 3					
	Model coefficients					Effect size
	F	*SE*	*df1*	*df2*	*p*	η_p^2
Within-subjects effects						
Retrieval	2.66	1.51	1	60	.11	.13
Time	0.00	1.51	1	60	1.00	<.001
Retrieval × Time	0.01	2.13	1	60	.94	<.001

Note. N = 21. Retrieval = frequently retrieved memory vs. averaged non-retrieved positive memories. Time = Session 1 vs. Session 3. The dependent variable is the involuntary memories score.

Appendix D

Table 13.

Multiple Linear Regression Estimates from Dataset 1 with Event Centrality of the Frequently Retrieved Memory During Session 2 as Dependent Variable (Hypothesis 4)

	Model 4						
	Model coefficients				Effect size		
	b	*SE*	*t*	*p*	f^2	95% CI	
						lower	upper
Variables							
Accessibility S2	-0.02	0.12	-0.16	.88	-0.05	-0.77	0.68
Accessibility S1	-0.12	0.06	-2.14	.09	-0.64	-1.41	0.13
Event Centrality S1	0.55	0.21	2.62	.05	0.73	0.01	1.45
F (df)	3.23 (3, 5)						
P	.12						
R^2_{adj}	0.46						

Note. $N = 9$. The dependent variable in this model is the event centrality score of the frequently retrieved memory during Session 2. Accessibility S2 = the accessibility score of the frequently retrieved memory during Session 2. Accessibility S1 = the accessibility score of the frequently retrieved memory during Session 1. Event Centrality S1 = the event centrality score of the frequently retrieved memory during Session 1. *SE* represents the standard error, *df* represents the degrees of freedom. 95% CI represents the 95% confidence interval. *** indicates a *p*-value <.001.

Table 14.

Multiple Linear Regression Estimates from Dataset 2 with Event Centrality of the Frequently Retrieved Memory During Session 2 as Dependent Variable (Hypothesis 4)

	Model 4						
	Model coefficients				Effect size		
	b	*SE*	*t*	*p*	f^2	95% CI	
						lower	upper
Variables							
Accessibility S2	0.01	0.05	0.27	.79	0.06	-0.43	0.55
Accessibility S1	0.05	0.06	0.92	.37	0.21	-0.27	0.69
Event Centrality S1	0.54	0.11	4.86	<.001 ***	0.73	0.41	1.04
F (df)	10.38 (3, 17)						
P	<.001						
R^2_{adj}	0.58						

Note. $N = 21$. The dependent variable in this model is the event centrality score of the frequently retrieved memory during Session 2. Accessibility S2 = the accessibility score of the frequently retrieved memory during Session 2. Accessibility S1 = the accessibility score of the frequently retrieved memory during Session 1. Event Centrality S1 = the event centrality score of the frequently retrieved memory during Session 1. *SE* represents the standard error, *df* represents the degrees of freedom. 95% CI represents the 95% confidence interval. *** indicates a *p*-value <.001.

Table 15.

Multiple Linear Regression Estimates from Dataset 1 with Involuntary Memories of the Frequently Retrieved Memory During Session 3 as Dependent Variable (Hypothesis 5)

	Model 5						
	Model coefficients				Effect size		
	b	*SE*	*t*	*p*	f^2	95% CI	
						lower	upper
Variables							
Event Centrality S2	-0.14	0.20	-0.70	.52	-0.34	-1.62	0.93
Event Centrality S1	0.25	0.17	-1.47	.20	0.82	-0.61	2.24
Invol. Memories S1	-0.01	0.19	-0.08	.94	-0.04	-1.28	1.21
F (df)	1.41 (3, 5)						
P	.34						
R^2_{adj}	0.13						

Note. $N = 9$. The dependent variable in this model is the involuntary memories score of the frequently retrieved memory during Session 3. Event Centrality S2 = the event centrality score of the frequently retrieved memory during Session 2. *Event Centrality S1* = the event centrality score of the frequently retrieved memory during Session 1. Invol. Memories S1 = the involuntary memories score of the frequently retrieved memory during Session 1. *SE* represents the standard error, *df* represents the degrees of freedom. 95% CI represents the 95% confidence interval. * indicates a *p*-value <.05.

Table 16.

Multiple Linear Regression Estimates from Dataset 2 with Involuntary Memories of the Frequently Retrieved Memory During Session 3 as Dependent Variable (Hypothesis 5)

	Model 5						
	Model coefficients				Effect size		
	b	*SE*	*t*	*p*	f^2	95% CI	
						lower	upper
Variables							
Event Centrality S2	-0.17	0.48	-0.36	.73	-0.11	-0.74	0.52
Event Centrality S1	0.31	0.36	0.87	.40	0.26	-0.37	0.89
Invol. Memories S1	0.60	0.22	2.68	.02*	0.54	0.11	0.96
F (df)	3.31 (3, 17)						
P	.05						
R^2_{adj}	0.26						

Note. $N = 21$. The dependent variable in this model is the involuntary memories score of the frequently retrieved memory during Session 3. Event Centrality S2 = the event centrality score of the frequently retrieved memory during Session 2. Event Centrality S1 = the event centrality score of the frequently retrieved memory during Session 1. Invol. Memories S1 = the involuntary memories score of the frequently retrieved memory during Session 1. *SE* represents the standard error, *df* represents the degrees of freedom. 95% CI represents the 95% confidence interval. * indicates a *p*-value <.05.

Table 17.

Multiple Linear Regression Estimates from Dataset 1 with Accessibility of the Non-Retrieved Memories During Session 2 as Dependent Variable (Hypothesis 6)

	Model 6						
	Model coefficients				Effect size		
	b	*SE*	*t*	*p*	f^2	95% CI	
						lower	upper
Variables							
Accessibility S2	0.49	0.34	1.43	.21	0.41	-0.33	1.14
Accessibility S1	-0.50	0.17	-2.76	.04*	-0.80	-1.55	-0.06
Accessibility NR S1	1.33	0.65	2.06	.10	0.65	-0.16	1.46
F (df)	3.93 (3, 5)						
p	.09						
R^2_{adj}	0.52						

Note. $N = 9$. The dependent variable in this model is the averaged accessibility score of the non-retrieved memories during Session 2. Accessibility S2 = the accessibility score of the frequently retrieved memory during Session 2. Accessibility S1 = the accessibility score of the frequently retrieved memory during Session 1. Accessibility NR S1 = the averaged accessibility score of the non-retrieved memories during Session 1. *SE* represents the standard error, *df* represents the degrees of freedom. 95% CI represents the 95% confidence interval. *** indicates a *p*-value < .001.

Table 18.

Multiple Linear Regression Estimates from Dataset 2 with Accessibility of the Non-Retrieved Memories During Session 2 as Dependent Variable (Hypothesis 6)

	Model 6						
	Model coefficients				Effect size		
	b	*SE*	*t*	*p*	f^2	95% CI	
Variables						lower	upper
Accessibility S2	0.25	0.13	1.89	.08	0.40	-0.05	0.84
Accessibility S1	-0.09	0.12	-0.74	.47	-0.14	-0.55	0.27
Accessibility NR S1	0.71	0.15	4.67	<.001 ***	0.67	0.37	0.97
F (df)	16.19 (3, 17)						
p	<.001***						
R^2_{adj}	0.70						

Note. N = 21. The dependent variable in this model is the averaged accessibility score of the non-retrieved memories during Session 2. Accessibility S2 = the accessibility score of the frequently retrieved memory during Session 2. Accessibility S1 = the accessibility score of the frequently retrieved memory during Session 1. Accessibility NR S1 = the averaged accessibility score of the non-retrieved memories during Session 1. *SE* represents the standard error, *df* represents the degrees of freedom. 95% CI represents the 95% confidence interval. *** indicates a *p*-value < .001.

Table 19.

Multiple Linear Regression Estimates from Dataset 1 with Accessibility of the Negative Memories During Session 2 as Dependent Variable (Hypothesis 7)

	Model 7						
	Model coefficients				Effect size		
	b	*SE*	*t*	*p*	f^2	95% CI	
						lower	upper
Variables							
Accessibility S1	0.06	0.09	0.66	.54	0.20	-0.59	1.00
Event Centrality NM S1	0.70	0.33	2.16	.08	0.62	-0.12	1.37
Accessibility S1	-0.09	0.04	-2.02	.10	-0.59	-1.34	0.16
F (df1, df2)	2.84 (3, 5)						
p	.14						
R^2_{adj}	0.41						

Note. N = 9. The dependent variable in this model is the averaged accessibility score of the non-retrieved memories during Session 2. Accessibility S2 = the accessibility score of the frequently retrieved memory during Session 2. Event Centrality NM S1 = the averaged event centrality score of the negative (non-retrieved) memories during Session 1. Accessibility S1 = the accessibility score of the frequently retrieved memory during Session 1. *SE* represents the standard error, *df* represents the degrees of freedom. 95% CI represents the 95% confidence interval.

Table 20.

Multiple Linear Regression Estimates from Dataset 2 with Accessibility of the Negative Memories During Session 2 as Dependent Variable (Hypothesis 7)

	Model 7						
	Model coefficients				Effect size		
	b	*SE*	*t*	*p*	f^2	95% CI	
						lower	upper
Variables							
Accessibility S2	-0.01	0.05	-0.25	.54	-0.05	-0.50	0.40
Event Centrality NM S1	0.99	0.16	6.16	<.001***	0.88	0.58	1.18
Accessibility S1	-0.06	0.05	-1.19	.25	-0.25	-0.70	0.19
F (df1, df2)	12.82 (3, 17)						
p	<.001***						
R^2_{adj}	.64						

Note. $N = 21$. The dependent variable in this model is the averaged accessibility score of the non-retrieved memories during Session 2. Accessibility S2 = the accessibility score of the frequently retrieved memory during Session 2. Event Centrality NM S1 = the averaged event centrality score of the negative (non-retrieved) memories during Session 1. Accessibility S1 = the accessibility score of the frequently retrieved memory during Session 1. *SE* represents the standard error, *df* represents the degrees of freedom. 95% CI represents the 95% confidence interval.