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Electrophysiological Correlates of Saving-Enhanced Memory: Exploring Similarities to List-Method Directed Forgetting

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Abstract

People regularly outsource parts of their memory onto external memory stores like computers or smartphones. Such cognitive offloading can enhance subsequent memory performance, as referred to the saving-enhanced memory effect [Storm & Stone, 2015. Saving-enhanced memory: The benefits of saving on the learning and remembering of new information. *Psychological Science, 26*(2), 182-188]. The cognitive mechanisms of this effect are not clear to date, however similarities to list-method directed forgetting (LMDF) have been stated. Here, we want to examine in 52 participants the electrophysiological (EEG) correlates of the saving-enhanced memory effect and compare our results to earlier LMDF findings [Hanslmayr et al., 2012. Prefrontally driven downregulation of neural synchrony mediates goal-directed forgetting. *Journal of Neuroscience, 32*(42), 14742-14751]. For this purpose, EEG alpha power and alpha phase synchrony during the encoding of two word lists will be compared as a function of saving or no-saving. If saving-enhanced memory is related to LMDF, saving in comparison to no-saving between lists should reduce alpha power and alpha phase synchrony during List 2 encoding, two effects that have been related to List 2 encoding benefits and List 1 inhibition in the earlier LMDF work. Overall, the results of the present study will clarify how close the saving-enhanced memory effect is related (at the level of brain oscillations) to LMDF.

Introduction

Nowadays we regularly rely on digital devices to function as external memory stores (e.g., Sparrow, Liu, & Wegner, 2011). We outsource parts of our memory in order to reduce cognitive demands, hereby performing cognitive offloading (for a review, see Risko & Gilbert, 2016). Indeed, cognitive offloading helps us to reduce the amount of facts and knowledge that we would have to remember on our own, freeing cognitive resources for the processing of other information and other cognitively demanding tasks in general (Runge, Frings, & Tempel, 2019; Storm & Stone, 2015). For instance, saving previously encoded information onto a computer can improve memory for subsequently encoded other information, which has been referred to as saving-enhanced memory (Storm & Stone, 2015). In the experiments reported by Storm and Stone (2015), participants studied two word lists for later recall testing (repeatedly in six to eight trials using different item material). After study of List 1, participants either saved the list onto a computer and were told that they could reopen and relearn this list before recall testing (save trials) or exited the list without saving (no-save trials). After study of List 2, participants had to recall List 2 items first and List 1 items second in two separate free recall tests (with restudy of List 1 items between recall tests in save trials). The results showed that participants recalled more List 2 items in save trials than in no-save trials, which reflects the saving-enhanced memory effect. In the present study, we want to investigate the electrophysiological (EEG) correlates of this newly introduced saving-enhanced memory effect.

Saving enhanced memory – a variant of directed forgetting?

The precise mechanisms of the saving-enhanced memory effect are not clear to date. One possibility that has been suggested by Storm and Stone (2015) is that saving could function like an implicit forget cue, triggering List 1 as temporarily irrelevant because a file of this list can be reopened and thus restudied at some later time point before recall testing.

Indeed, research employing the list-method directed forgetting (LMDF) task demonstrated that cuing participants to intentionally forget previously studied information can enhance memory for subsequently studied other information. In the LMDF task, participants study two item lists. After study of List 1, they are either cued to forget this list (forget condition) or continue remembering this list (remember condition). After study of List 2, participants are tested in separate recall tests on List 1 and List 2 independent of original cuing. The typical finding is that the forget cue impairs recall of List 1 and improves recall of List 2, referred to as List 1 forgetting and List 2 enhancement (for a review, see Pastötter, Tempel, & Bäuml, 2017; Sahakyan, Delaney, Foster, & Abushanab, 2013). Different accounts have been suggested to explain LMDF, including one-mechanism (e.g., Geiselman, Bjork, & Fishman, 1983; Sahakyan & Kelley, 2002) and two-mechanism accounts (e.g., Sahakyan & Delaney, 2003; Pastötter & Bäuml, 2010).

Due to a number of dissociations that have been observed between LMDF effects (e.g., List 2 enhancement typically occurs without List 1 forgetting in item recognition tests; Benjamin, 2006; Pastötter, Kliegl, & Bäuml, 2016), two-mechanism accounts are commonly preferred as theoretical explanations of LMDF. For instance, Sahakyan and Delaney (2003) proposed a two-mechanism account that attributes List 1 forgetting to a change in internal context (as response to the forget cue when participants think of something other than the item material), inducing context-dependent forgetting, and List 2 enhancement to a change in encoding strategy, with more elaborate encoding of List 2 items after a forget cue than after a remember cue. In contrast, Pastötter and Bäuml (2010) attributed List 1 forgetting to retrieval inhibition, which reduces accessibility of List 1 context during List 2 encoding and final test, and List 2 enhancement to a reset of encoding processes. According to the reset-of-encoding hypothesis, the forget cue abolishes memory load and inattentional encoding that would build up when both lists were to be remembered. This makes the encoding of List 2 items as

effective as the encoding of List 1 items (see Pastötter, Kliegl, & Bäuml, 2012, for an updated two-mechanism account that assumes an additional role of inhibition-induced interference reduction for List 2 enhancement). Runge et al. (2019) showed that short-term effects like a reset of encoding might also play a role in saving-enhanced memory. Besides presenting a replication of saving-enhanced memory, the study showed a related benefit effect for modular arithmetic tasks. Saving recently encoded verbal material benefitted performance in unrelated modular arithmetic tasks that have often been considered an index for working-memory capacity (e.g., Beilock & Carr, 2005; Bellinger, DeCaro, & Raslton, 2015; Mattarella-Micke et al., 2011). Hence, a save cue seems to abolish memory load similar to a forget cue, providing more attentional/cognitive resources for subsequent cognitively demanding tasks, not least for the encoding of subsequently presented verbal item material.

Neurocognitive evidence for the two-mechanism account of Pastötter and Bäuml (2010) arose from an LMDF study by Hanslmayr et al. (2012) that examined EEG alpha oscillations (around 10 Hz) during the encoding of the two item lists (see also Bäuml, Hanslmayr, Pastötter, & Klimesch, 2008, for an LMDF study that focused on EEG activity during List 2 encoding). This study demonstrated that alpha amplitude (9-11 Hz) during item encoding increased from List 1 to List 2 in the remember condition, but not in the forget condition. Because increases of alpha amplitude during item encoding have been attributed to increases in memory load and inattention (Sederberg et al., 2006; Pastötter, Bäuml, & Hanslmayr, 2008; Pastötter, Schicker, Niedernhuber, & Bäuml, 2011), this finding suggests that the forget cue resets neural activity during List 2 encoding back to List 1 level and thus improves the encoding of List 2 items, which fits with the reset-of-encoding hypothesis by Pastötter and Bäuml (2010). In addition, Hanslmayr et al. (2012) showed that long-range phase synchrony in the upper alpha/lower beta frequency range (11-18 Hz), measured by means of the phase-locking value (PLV, Lachaux et al., 1999), decreased from List 1

encoding to List 2 encoding in the forget condition, but not in the remember condition. Following the view that memories are represented in widely distributed cortical networks (Fuster, 1997), the decrease in phase synchrony in the forget condition may reflect the inhibition of List 1 context (Pastötter & Bäuml, 2010; for a neurocognitive review on inhibitory forgetting, see Anderson & Hanslmayr, 2014).

The Present Study

The goal of the present study is to investigate the EEG correlates of the saving-enhanced memory effect. Specifically, following the proposal by Storm and Stone (2015) and the findings of Runge et al. (2019), we want to test the hypothesis that saving between two item lists is a variant of LMDF. As in LMDF, multiple mechanisms might account for benefits of saving, possibly affecting both the encoding and the recall of List-2 items. In LMDF, two of those mechanisms (reset of encoding for List 2 and suppression of List 1) have been linked to separate EEG correlates during List 2 encoding (Hanslmayr et al., 2012). The findings by Runge et al. (2019) suggest that better encoding due to a reset of encoding might also account for the saving-enhanced memory effect. Accordingly, we would expect that alpha amplitude during item encoding increases from List 1 to List 2 in the no-save condition, but not in the save condition, reflecting a reset of encoding (Hanslmayr et al., 2012). Furthermore, if a save cue is indeed a variant of a forget cue that does not only abolish short-term memory load but also impairs accessibility of offloaded List 1 items in long-term memory, we would expect to find possible correlates of such suppression in the EEG. Hence, we want to examine whether long-range phase synchrony in the upper alpha/lower beta frequency range decreases from List 1 encoding to List 2 encoding in save trials, but not in no-save trials, possibly reflecting the inhibition of List 1 (Hanslmayr et al., 2012) (for an overview of our hypotheses, proposed sampling plans, analysis and prospective interpretations see Table 1). Overall, such findings would clarify how close the saving-

enhanced memory effect is related (at the level of brain oscillations) to LMDF. It should be noted that while the present study aims at addressing the question of whether saving-enhanced memory involves similar mechanisms as LMDF, it does not aim at directly comparing saving-enhanced memory and LMDF in a single experiment.

Method

Participants

Following the behavioral study by Runge et al. (2019), who reported an effect size $dz = 0.36$ for the saving-enhanced memory effect, and with the additional input parameters $\alpha = .05$ and $1\text{-}\beta = .80$ for a one-sided paired *t* test, we calculated a sample size of 50 participants using G*Power 3.1.9.2 (Faul, Erdfelder, & Buchner, 2007). Yet for reasons of balancing, we need a multiple of four. Therefore, we will run the experiment with a total sample size of 52 participants. This is more than twice the sample size that went into the EEG analysis in the LMDF study by Hanslmayr et al. (2012; $n = 22$). Participants will be undergraduate students at the University of Trier; they will participate in the study for course credit or payment (20 Euro). All participants will give written informed consent before examination. The study will be conducted in accordance with the Declaration of Helsinki; it is approved by the local ethical review committee at the University of Trier (reference number: 50/2017).

Exclusion Criteria

Individuals who do not have normal or corrected-to-normal vision and individuals with history of neurological disease will not participate in this study. Participants who will not follow task instructions (e.g., in the distractor task) will be excluded and replaced by new participants with the same balancing of item material and experimental trials. Regarding EEG analysis, participants with more than 5 interpolated channels (out of 65 electrodes) will be

excluded and replaced by new participants. In addition, participants with less than 15 (out of 30) artifact-free EEG segments per condition and list will be excluded and replaced (see Hanslmayr, Spitzer, & Bäuml, 2008, for a simulation experiment showing that EEG oscillatory [de]synchronization patterns stabilize with 15 segments per condition). No participants will be excluded based on (individual differences in) behavioral results.

Design

Saving will be manipulated within participants (save vs. no-save trials). Four save and four no-save trials will be conducted for each participant.

Materials

The experiment will be designed and conducted with E-prime software (Version 2.0, Psychology Software Tools, Sharpsburg, PA). Across eight trials (four save trials, four no-save trials), participants are going to learn and recall 16 single word lists of 10 common nouns each (four to eight letters long). During breaks between trials, participants are going to solve Sudokus, which will be printed and solved by participants with a pen.

Procedure

The overall procedure will be very similar to the procedure used by Storm and Stone (2015) in Experiment 1 (see Figure 1) with slight changes in the presentation of word lists in order to allow trial based analysis of EEG oscillatory activities in stimulus-induced power changes and long-range phase synchrony. Each word list will be equally often presented in save or no-save trials, and as the first list (List 1) or second list (List 2) of a trial, all balanced between participants. Identical to Runge et al. (2019), this balancing will be achieved by running four different versions of the experiment. Equal numbers of participants will be assigned to each version. Every participant will run through four save (S) and four no-save (N) trials. Depending on the experimental version, participants will be assigned to one of two fixed

sequences of trials (SNNSSNNS, NSSNNSSN). This assures that, across participants, at each moment during the experiment equally often save and no-save trails will appear. Yet, the participants will be told that the sequence of trials would be random. To ensure that the participants can easier distinguish the 16 word lists from another, in the experiment lists are numbered consecutively starting with list 1A for the first list of the first trial and list 1B for the second list of the first trial continuing up to lists 8A and 8B for the last trial (note, throughout this manuscript we keep calling all first lists of each trial List 1 and all second lists of each trial List 2). Besides some basic verbal instructions at the beginning of the experiment concerning requested behavior (e.g. to move as little as possible in order to reduce artifacts in the EEG) all later instructions will be presented via screen within the automatized experimental procedure.

The crucial aspect of the experimental procedure is the cue following List 1 encoding (save vs. no-save trials). The 10 nouns of this list will be presented one below the other on a single screen, with the list of nouns starting in the upper half of the screen, until all 10 nouns are visible at once (viewing distance: 65 cm; font: Times New Roman; font size: 32; vertical gap between words: 1.9 cm/~0.75 inch; size of words (corrected for angle of vision): 0.8 cm (0.71 cm)/ ~ 0.31 inch (0.28 inch). The presentation of each word will be preceded by a 2 s fixation cross that will be shown centrally to the position of the next word. 2 s after onset of each word, the next fixation cross will be shown (words 1 to 9) or the list will end (word 10) after 40 s. Participants will be instructed to always keep their focus on presented fixation crosses and the most recent word to appear. In order to ensure that participants will follow this instruction we will tell participants that an eye tracker captures their eye movements throughout the experiment. Note, although we will place an eye tracker below the screen, this eye tracker will not collect any data. After List 1 encoding, two different instructions can appear, depending on the type of trial. In save trials, participants will be instructed that List 1

would be saved and therefore accessible again for a second encoding phase. After this instruction, participants will have to press the key “s” in order to allegedly save List 1, triggering a message box that says that List 1 has now been saved. In contrast, in no-save trials, participants will be told that List 1 would not be saved, which omits the possibility to relearn this list later on. In these trials, participants will have to press the key “n”, triggering a message box saying that List 1 has not been saved.

The procedural steps after the instruction of saving or not saving List 1 will be again identical across both types of trials. First, participants will study List 2 in the same way as they studied List 1. Again, the 10 nouns of the list will appear on the screen one below the other. Afterwards, participants will do a distractor task (counting backward in steps of three from a three-digit number for 30 s). Then, participants will have to recall List 2 in a free recall test, lasting 30 s, by typing all remembered words onto a blank screen so that their answers will be registered. In no-save trials, this recall test will be directly followed by the recall test for List 1 (30 s). In save trials, participants will get the possibility to relearn List 1 (with same item presentation order) before being tested on it. To get familiar with this procedure and the consequences of saving or not saving List 1, participants will run through one save and one no-save trial for practice. Afterwards participants will proceed through six experimental trials, i.e., three save trials and three no-save trials. Between trials, participants will have to fulfill an unrelated distractor task (solving a Sudoku for 1 min). A similar procedure with similar verbal material (same word length, similar amount of words per word list) have been used in previous studies (e.g. Runge et al., 2019; Storm & Stone, 2015). In these studies between 30% and 60% of the verbal material was recalled (despite changes in the amount of words per word lists). Therefore, we did not expect to find any bottom or ceiling effects regarding the use of our verbal material.

Recording of EEG data

During the encoding phase of Lists 1 and 2, scalp EEG will be recorded from 65 Ag/AgCl electrodes arranged according to the 10-10 electrode system with reference to FCz (EC80, Montage No. 1, Easycap, Herrsching, Germany) in a shielded booth (see Figure 2). Ground electrode will be placed at location AFz.

The electrooculogram (EOG) will be recorded from four bipolar channels, positioned on the inferior and superior regions of the left eye and the outer canthi of both eyes, in order to monitor the vertical and horizontal EOG. Electrode-skin impedance will be kept below 5 kΩ for all scalp and EOG electrodes. Signals will be digitalized with a sampling rate of 500 Hz and amplified between 0.016 Hz and 250 Hz (BrainAmp, BrainVision Recorder, v1.20, Brain Products, Gilching, Germany).

Preprocessing of EEG data

EEG recordings will be re-referenced offline against average reference and EOG corrected by using calibration data and generating individual EOG artifact coefficients, as implemented in BESA Research (v7.0, BESA Software, Gräfelfing, Germany). After EOG-correction, remaining artefacts will be marked by careful visual inspection. EEG signals of single electrodes showing heavy artifacts throughout the whole session will be interpolated using a spline interpolation in BESA research. Artifact-free EEG data will be segmented into epochs ranging from -3.0 to 3.0 s around the onset of words. To avoid filter artifacts at the edges of segments, time-frequency analyses will be restricted to intervals ranging from -2.0 to 2.0 s around word onset, which covers all time points of each list. For each subject, a maximum number of 30 segments per list and condition will go into analysis of time-frequency data.

Time-Frequency Decomposition

The EEG data will be transformed into the time-frequency domain using a complex demodulation algorithm, which is implemented in BESA Research 7.0 (see Hoechstetter et al., 2004). The algorithm consists of a multiplication of the time domain signal with a complex periodic exponential function, having a frequency equal to the frequency under analysis, and subsequent low-pass filtering. The low-pass filter is a finite impulse response filter of Gaussian shape in the time domain, which is related to the envelope of the moving window in wavelet analysis. The data will be filtered in a frequency range from 2 to 20 Hz. Time resolution will be set to 78.8 ms (full power width at half maximum; FWHM), and frequency resolution to 1.42 Hz (FWHM). Time-frequency data will be exported in bins of 50 ms and 1 Hz.

Analysis of Power Changes

Stimulus-induced power changes will be determined by calculating temporal-spectral evolution, that is, power changes during word presentation for all time-frequency points with power increases or decreases at time point *t* and frequency *f* related to mean power at frequency *f* over the prestimulus baseline interval (Pfurtscheller & Aranibar, 1977; Pfurtscheller & Lopes da Silva, 1999). Following Hanslmayr et al. (2012), the baseline interval will be set from -0.5 s to stimulus onset. Permutation-based cluster analysis (Maris & Oostenveld, 2007) will be calculated to examine the interaction between conditions (save, no-save) and lists (List 1, List 2), as implemented in BESA Statistics (v2.0, BESA Software).

In the first step, non-spatial cluster analysis will be calculated, in which time-frequency spectrograms of power changes will be averaged across the 65 electrodes and differences in averaged power changes between List 1 and List 2 will be contrasted between conditions in single *t* tests on difference scores in order to test the interaction between the

factors of condition (save, no-save) and list (List 1, List 2) for power changes (as referred to in Table 1). Specifically, two-tailed *t* tests for all time-frequency points (41 [time bins during stimulus presentation] * 19 [frequency bins from 2 to 20 Hz]) will be calculated and clusters of contiguous significant data points will be derived. For each empirical cluster, the sum of *t* values of the single significant data points will be kept as a test statistic. Random permutation tests (10000 runs) will be run in which the sum test statistic will be repeatedly calculated for randomly shuffled data sets, with the data randomly reordered across save and no-save conditions and the permutation-based cluster with the highest sum of *t* values will be kept. Test statistics for empirical clusters will be compared to the null distribution of the permutation-based clusters and a *p* value for the empirically derived cluster(s) will be calculated.

In the second step, empirical clusters with a *p* value below .05 will go into analysis of spatial topography. For each cluster, power changes will be averaged across data points of the cluster's maximum time range and maximum frequency range, separately for each electrode. Differences in averaged power changes between List 1 and List 2 will be contrasted between conditions (save, no-save). Two-tailed t tests will be calculated for all electrodes. Spatial topographies will be identified and plotted by considering those electrodes that are significant in the *t* test. No additional cluster analysis will be calculated. Thus, both clustered and scattered spatial effects will be considered in spatial analysis.

Finally, power changes in a cluster's time-frequency range will be averaged across significant electrodes and differences between lists (List 1, List 2) will be analyzed in planned comparisons separately for the two conditions (save, no-save) with SPSS (Version 24.0), expecting a significant increase of (alpha) power change from List 1 to List 2 in the no-save condition, but no significant difference in (alpha) power change between lists in the save condition. Time courses of significant effects will be plotted, respectively.

Analysis of Phase Synchrony

Before phase synchrony calculation, a current source density (CSD) transformation will applied to the EEG data using BESA Research. The phase synchrony values will be calculated following the procedure of Lachaux et al. (1999), as implemented in BESA Research. As described in the study by Hanslmayr et al. (2012), this procedure delivers a value that ranges from 0 to 1, indicating minimal to maximal phase synchrony, respectively. Phase locking values (PLVs) will be calculated for all possible pairs of electrodes, all time bins from -2.0 to 2.0 s around word onset, and all frequency bins from 2 to 20 Hz, separately for conditions (save, no-save) and lists (List 1, List 2).

In the first step, non-spatial cluster analysis will be calculated. PLVs will be averaged across the 41 time bins and 65 electrodes and differences in averaged PLVs between List 1 and List 2 will be contrasted between conditions in single *t* tests on difference scores in order to test the interaction between the factors of condition (save, no-save) and list (List 1, List 2) for PLVs (as referred to in Table 1). Two-tailed *t* tests for all frequency points (19 [frequency bins from 2 to 20 Hz]) will be calculated and clusters of contiguous significant frequency points will be derived. For each empirical cluster, the sum of *t* values of the single significant frequency points will be kept as a test statistic. Random permutation tests (10000 runs) will be run in which the sum test statistic will be repeatedly calculated for randomly shuffled data sets, with the data randomly reordered across save and no-save conditions and the permutation-based cluster with the highest sum of *t* values will be kept. Test statistics for empirical clusters will be compared to the null distribution of the permutation-based clusters and a *p* value for the empirically derived cluster(s) will be calculated.

In the second step, empirical clusters with a *p* value below .05 will go into analysis of spatial topography. For each cluster, PLVs will be averaged across data points of the cluster's maximum time range and maximum frequency range, separately for each electrode pair.

Differences in PLVs between List 1 and List 2 will be contrasted between conditions (save, no-save). Two-tailed t tests will be calculated for all electrode pairs. Spatial topographies will be identified and plotted by considering those electrodes that are significant in the *t* test. No additional cluster analysis will be calculated. The plotting of spatial topographies will be used to graphically describe the distribution of PLV effects over the scalp; no additional inferential statistics regarding the spatial distribution effects will be calculated.

Finally, PLVs in a cluster's frequency range will be averaged across significant electrodes and differences between lists (List 1, List 2) will be analyzed in planned comparisons separately for the two conditions (save, no-save) with SPSS (Version 24.0), expecting a significant decrease of (upper alpha/lower beta) PLVs from List 1 to List 2 in the save condition, but no significant difference in (upper alpha/lower beta) PLVs in the no-save condition. Time courses of significant effects will be plotted, respectively.

Because trial numbers can bias phase synchronization measures, following Hanslmayr et al. (2012), it will be statistically checked whether there are significant differences between trial numbers across conditions and lists. In addition, control analyses will be calculated (for both power change and PLVs) in which the number of trials will be equated by means of randomly selecting the minimum number of available trials (≥ 15) per condition and list for each subject.

Note that in contrast to the behavioral analysis, in which a directional alternative hypothesis will be used (see below) based on expectation of a directional saving-enhanced memory effect (e.g., Runge et al., 2019; Storm & Stone, 2015), non-directional alternative hypothesis were used in the EEG analyses in order to leave some room for exploratory analysis (e.g., effects that are opposite direction to the ones expected on the basis of the earlier EEG work in LMDF).

Analysis of Behavioral Data

Behavioral data will be analyzed using SPSS (Version 24.0). The mean number of words correctly recalled in the List 2 recall test(s) will be analyzed between experimental conditions (save vs. no-save) by calculating a one-sided paired *t* test. This comparison of two conditions is equivalent to the common approach in LMDF where a forget condition is compared with a remember condition. Hence, the variable of interest is a difference score derived from these comparisons. An actual baseline condition is not common in these fields of research and would not serve much purpose. In addition, a possible influence of trial block (Block 1 vs. Block 2 vs. Block 3) on these difference scores will be examined in repeated-measures analysis of variance with the two factors of experimental condition and trial block. The variable trial block divides all trials (excluding practice trials) into three blocks. Block 1 includes the first save trial and the first no-save trial, Block 2 the second save trial and the second no-save trial, and Block 3 the third save trial and the third no-save trial. Hence, this analysis will examine possible variations of the difference scores mentioned above throughout the experiment. For the mean number of words correctly recalled from List 1 the same analyses goes as for the words correctly recalled from List 2. Finding a behavioral saving-enhanced memory effect is a prerequisite for all EEG based analyses mentioned. Note, that the behavioral saving-enhanced memory effect has been replicated several times with the method we are going to use here (e.g., Runge et al., 2019; Storm & Stone, 2015).

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Author Contribution

All four authors designed the experiment, and contributed to the writing of the stage 1 manuscript.

Data Accessibility

All authors agree to share the raw data, digital study, materials, analysis code, and laboratory log for all published results on a recognized repository.

Abbreviation list

CSD: current source density

EEG: electroencephalography

EOG: electrooculogram

FWHM: full power width at half maximum

LMDF: list-method directed forgetting

N: no-save trials

PLV: phase-locking value

S: save trials

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Tables

Table 1. Overview of the hypotheses, the proposed way of analyzing them, the respective sampling plan and prospective interpretation

	Hypothesis	Analysis	Sampling Plan	Interpretation
1	H0: No difference in List 2 recall between conditions (save vs. no-save trials) H1 (*expected*): Higher recall for List 2 items in save trials compared to no-save trials	One-sided paired *t* test with correct List 2 recall as DV and condition (save vs. no-save) as IV	Calculation of required sample size: $n = 50$ (running $n = 52$ for reasons of balancing) Input parameters: $dz = 0.36$ (as reported by Runge et al., 2019), $\alpha = .05$, and $1\text{-}\beta = .80$	No significant NHST: Failed replication of the behavioral saving-enhanced memory effect Significant NHST: Replication of the behavioral saving-enhanced memory effect
2	H0: No significant interaction between the factors of condition (save, no-save) and list (List 1, List 2) for alpha power change H1 (*expected*): Significant interaction between the factors of condition (save, no-save) and list (List 1, List 2) for alpha power change → Increase of alpha power change during item encoding from List 1 to List 2 in no-save trials but not in save trials	Non-spatial cluster analyses of the interaction effect based on non-parametric permutation testing (Maris & Oostenveld, 2007) → planned comparisons (*t* tests) averaged over significant electrodes	Performing power calculations for statistical analyses that involve high-dimensional data like the present time-frequency EEG data is challenging. $n = 52$ would be more than twice the sample size analyzed in the study by Hanslmayr et al. (2012; $n = 22$), suggesting large enough power for this analysis	No significant alpha cluster: No direct evidence for an encoding reset as it has been observed in LMDF Significant alpha cluster, planned comparisons as expected: Evidence for an encoding reset
3	H0: No significant interaction between the factors of condition (save, no-save) and list (List 1, List 2) for upper alpha/lower beta PLVs	Non-spatial cluster analyses of the interaction effect based on non-parametric permutation testing (Maris &	Performing power calculations for statistical analyses that involve high-dimensional data like the present time-frequency EEG data is challenging.	No significant upper alpha/lower beta cluster: No direct evidence for List 1 inhibition as it has been

H1 (*expected*): significant interaction between the factors of condition (save, no-save) and list (List 1, List 2) for upper alpha/lower beta PLVs → Decrease of upper alpha/lower beta PLVs during item encoding from List 1 to List 2 encoding in save trials but not in no-save trials	Oostenveld, 2007) → planned comparisons (*t* tests) averaged over significant electrodes	*n* = 52 would be more than twice the sample size analyzed in the study by Hanslmayr et al. (2012; *n* = 22), suggesting large enough power for this analysis	observed in LMDF Significant upper alpha/lower beta cluster, planned comparisons as expected: Evidence for List 1 inhibition

Figures

Figure 1

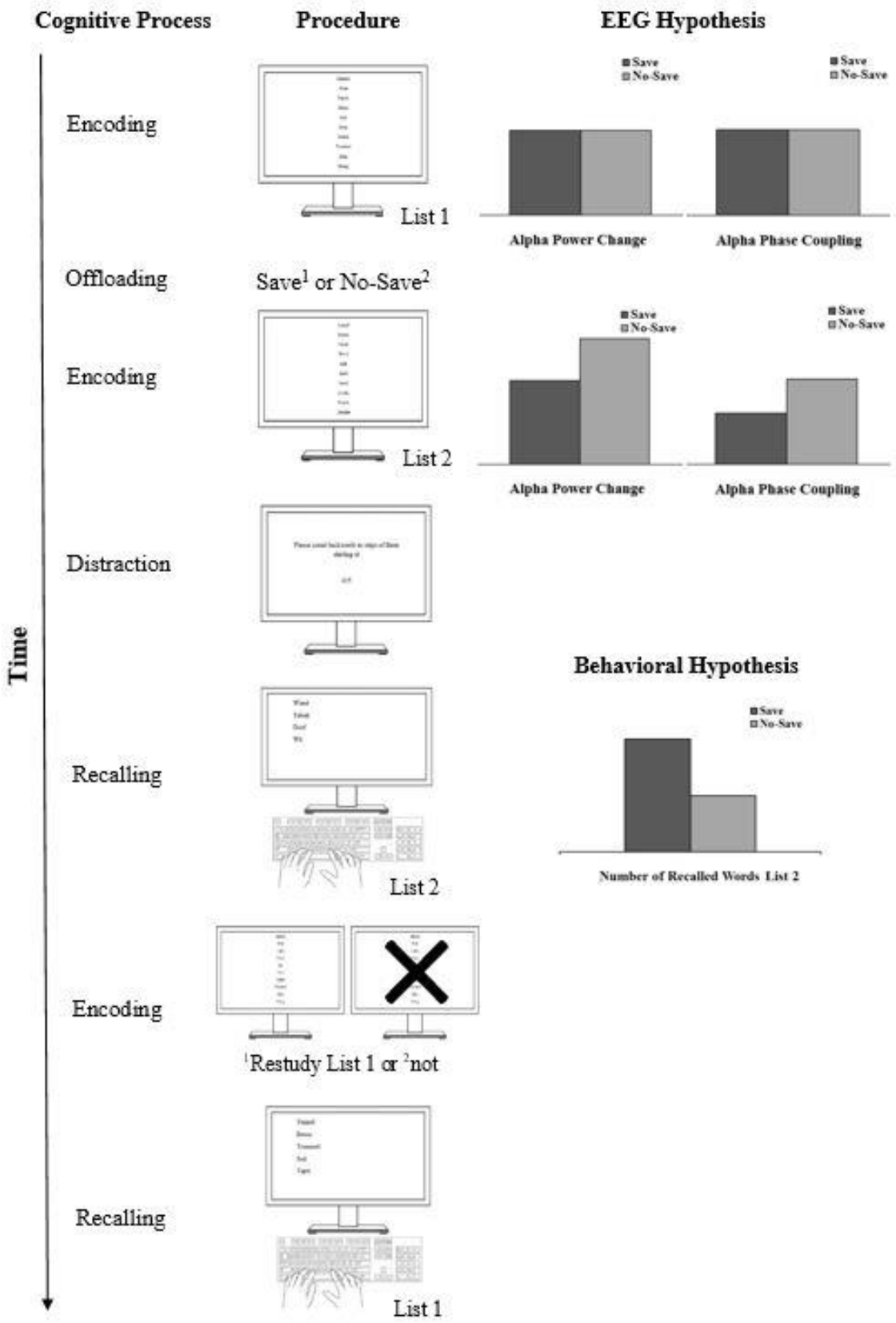

Figure 1. Sample trial sequence with hypothesized EEG and behavioral results. After study of List 1, participants will be instructed either to save this file or not to save it. When requested to save the file participants will recognize at this point that they can relearn List 1 later on. Next, participants will study List 2 and afterwards solve a distractor task (counting backwards). The test for List 2 will follow. In save trials, participants will relearn List 1 before being tested for this list. In no-save trials, the test for List 1 will directly follow the test for List 2. From List 1 encoding to List 2 encoding we expect to find an increase in alpha power in no-save trails (not in save trials) and a decrease in alpha phase coupling in save trials (not in no-save trials). Besides, we expect to replicate the saving-enhancement effect that is better recall of List 2 items in save trials than in no-save trials.

Figure 2

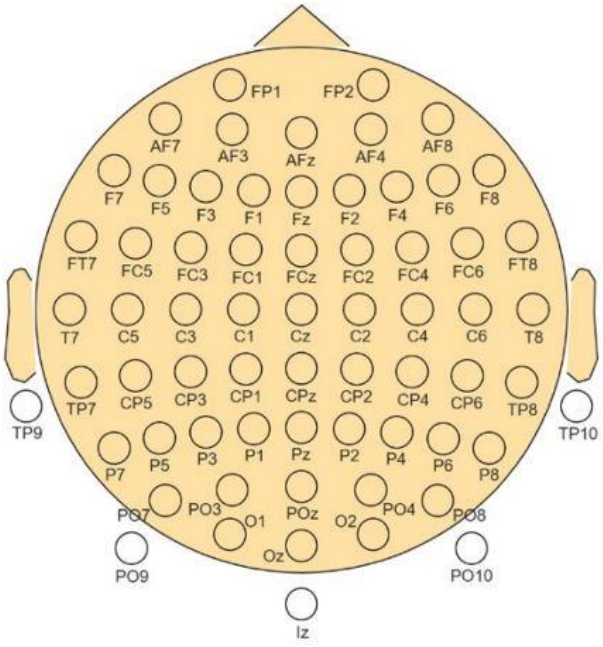

Figure 2. Montage of the 65 scalp electrodes. FCz will serve as original reference (additional ground electrode at FPz; four additional EOG electrodes will be used).