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May the source be with you! Electrophysiological correlates of retrieval orientation are associated with source memory performance☆

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ABSTRACT

Successful source memory retrieval is assumed to rely on intact preretrieval processes, such as retrieval orientation (RO). RO is the specialized processing of retrieval cues, depending on the type of information, memory is searched for. In a previous study, a positive frontal slow wave RO ERP effect was interpreted as reflecting memory search for self-relevant information. However, such a functional interpretation is hampered by the use of retrieval strategies as a consequence of which target source information can be indirectly inferred from the correct classification of non-target source information. To overcome this limitation, the present study compared two types of source information (i.e. color or character information) by asking participants to remember details within each source type and thus enforcing the selective retrieval of target information. Consistent with previous research, a positive frontal ERP component (600–800 ms post-stimulus) differentiated between correct rejections in both tasks, probably reflecting memory search for self-relevant information. Moreover, the RO ERP effect was associated with better source memory performance, providing evidence for the beneficial effect of ROs for memory retrieval. This relationship might be covered in memory exclusion tasks due to non-target retrieval.

1. Introduction

In our daily lives, it is often required not only to remember that you know a person, but also what additional information you possess about this particular person– e.g. if this person is good or bad. Retrieval of such source information from memory is thus a very basic but highly relevant skill.

The situation described above is a classical source memory task, whereby source refers to characteristics that define the circumstances (e.g. spatial, temporal, or social) under which a memory is acquired (Johnson, Hashtroudi, & Lindsay, 1993). For example, it might be of high relevance to remember if the insurance agent who decides about one's proposal was rude or helpful. Interestingly, source memory is not thought of as a single association in form of a tag, but rather as a decision process, based on the evaluation of several activated memory records (Johnson et al., 1993; Mitchell & MacPherson, 2017). Accordingly, remembering whether a person is good or bad does include more than the retrieval of a single association. Instead, it requires the retrieval and evaluation of several associations (e.g. one could remember that the insurance agent had evil-looking eyes, cursed a lot, and hit the table and therefore conclude that this person was rude).

Making judgements about the origin of a source is thought to rely on strategic retrieval processes, i.e. control processes, which are employed during memory retrieval in order to flexibly adapt memory retrieval to alternating retrieval goals (Bridger, Herron, Elward, & Wilding, 2009; Herron & Wilding, 2005; see Moscovitch, 1992). Their use depends on the demands that are imposed by the relevant memory task (Bridger et al., 2009; Herron & Wilding, 2005; Mecklinger, 2010). A concept, which is closely related to strategic retrieval processes of this kind, is retrieval orientation. Retrieval orientation is defined as the specific form of processing, which is applied to a retrieval cue (Rugg & Wilding, 2000) and was argued to facilitate the retrieval of task-relevant details (Bridger & Mecklinger, 2012; Bridger et al., 2009). The neural correlate of this specialized processing can be observed by comparing neural activity for varying types of source information or retrieval goals. One way to study neural correlates of retrieval orientation is to contrast event-related potentials (ERPs) elicited by correctly rejected new items across different retrieval goals. The benefit of using unstudied items is that it

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avoids confounding retrieval orientation effects with retrieval success, as no information can be retrieved on new items (Rosburg, Mecklinger, & Johansson, 2011; Rugg & Wilding, 2000). The ERP correlate of retrieval orientation (the RO ERP effect) thus depends on source type or retrieval goals, and is thought to reflect processes, which are strategically engaged depending on task demands (Bridger et al., 2009). Consequently, the topographic distribution and the temporal characteristics of these effects vary across tasks and studies (e.g. Bridger et al., 2009; Bridger & Mecklinger, 2012).

A majority of studies investigates strategic retrieval and retrieval orientation in a memory exclusion task (see Jacoby, 1991). The critical feature of the memory exclusion task is the differentiation between subsets of studied items during retrieval. One group of studied items is arbitrarily defined as the target category and has to be detected, whereas the remaining group, together with new, unstudied items, represents the non-target category and has to be rejected. Target assignment switches during the experiment. Defining a target category should induce a retrieval orientation, as it sets a retrieval goal, which is tailored to the specific target category.

Such a memory exclusion task was used in a study by Rosburg et al. (2011), who studied retrieval orientations in reality monitoring. In general, in a reality monitoring task, participants are required to distinguish between actually perceived source information and internally generated (i.e. self-generated) source information (Johnson & Raye, 1981). Rosburg et al. (2011) presented participants with object names that were either followed by a picture of the denoted object (perceive condition) or by an instruction to imagine a picture of the object (imagine condition) at encoding. In a consecutive memory test, participants performed a memory exclusion task. During this task, they were to detect perceived items as targets and to reject imagined items, and vice versa. Comparing ERPs elicited by correct rejections between both source type conditions (i.e. target designations), revealed a sustained positive slow wave at frontal recording sites for the imagine condition relative to the perceive condition. This effect was present from 600 to 1100 ms post-stimulus onset and maximal around 600–800 ms. Time window and topography of this frontal RO ERP effect resemble an effect of another ERP study, which used an auditory reality monitoring task (Leynes, Cairns, & Crawford, 2005). In this study, participants were to remember if a stimulus was previously heard in a male or female voice or was completely new (external source monitoring) or if a stimulus was previously heard, self-generated, or completely new (reality monitoring). Correct rejections in the reality monitoring task were similarly associated with a larger frontal positivity, compared to correct rejections in the external source monitoring task in a time window from 1000 to 1200 ms. Rosburg et al. (2011) point out that, as both studies reveal a similar pattern of results by using different task modalities, it is likely that the RO ERP effect reflects processing associated with the retrieval of self-generated information. Interestingly, Rosburg et al. (2011) discussed whether higher self-relevance could account for the more positive frontal ERP deflections in the imagine condition, as self-referential processing has been associated with prefrontal brain regions (Lundstrom et al., 2003; Vinogradov, Luks, Schulman, & Simpson, 2008).

However, a functional interpretation of the RO ERP effect is hampered by the possibility that different retrieval strategies can be used in memory exclusion tasks and source monitoring tasks. For memory exclusion tasks, Bridger and Mecklinger (2012) reasoned that, next to the target priorization strategy, in which only target information is prioritized (Herron & Rugg, 2003a), participants could also ignore the target/non-target distinction and retrieve both types of information (Jacoby, 1991). By using such a non-priorization strategy, similar strategic retrieval orientations are used for targets and non-targets. As a consequence, ERPs to correct rejections would not differ as a function of which information is targeted (Bridger et al., 2009), confounding any ERP contrast between two retrieval conditions. Importantly, the possibility to use multiple targets for memory retrieval is not restricted to memory exclusion tasks only, but can occur in any task in which participants may infer the correct classification of target source information from knowing the correct classification of non-target source information, i.e. use a recall-to-reject strategy (Clark, 1992) on non-target information (Rosburg & Mecklinger, 2017). For example, a similar logic can be applied to the reality monitoring task in the Leynes et al. (2005) study, in which participants had to decide if a word had previously been self-generated, heard or was new. Participants could have inferred that an item was self-generated by remembering that they did not hear it and this could have complicated the functional interpretation of the RO ERP effect in their reality monitoring task as reflecting the priorization of self-relevant information.

Therefore, the first goal of the current study was to replicate the frontal RO ERP effect by using a modified source memory task, adapted to avoid confounding effects of non-target retrieval. In our modified source memory task, participants have to search for the task-relevant type of information, as they have to recover the studied information. Thus, in this setting participants are forced to adopt a task-specific retrieval orientation. In the current study, participants studied pictures of faces, together with an additional feature. The critical manipulation was the amount of self-relevance processing, which was required to associate a face with the feature of the study context. In one task (the color task), which is analogue to the perceived condition in Rosburg et al. (2011), participants had to learn the color of the depicted persons' t-shirt (orange or violet). As the critical feature (color) is a semantically poor perceptual feature, it includes fewer self-relevant processing. In the other task (the label task), participants had to learn the person's assignment to a group of either good or bad people (indicated by a label), which is a highly self-relevant information. If the frontal RO ERP effect reflects the search for self-relevant information, we expect to find more pronounced positive slow waves for correct rejections in the label task than in the color task. Further, this effect should show similar temporal and topographical characteristics as in the previous study (Rosburg et al., 2011).

By asking participants to focus on either a perceptual or a conceptual feature, the encoding focus was not uniform across conditions. However, the few studies that explored the impact of encoding focus (Leynes & Crawford, 2018; Leynes & Mok, 2017) report that encoding focus mainly affects ERPs to old items with negligible effects on correct rejections. Hence, any differences between the ERPs elicited by correct rejections should not reflect differences in encoding focus but the adaptation of task specific retrieval orientation.

An intriguing question is whether the adoption of a retrieval orientation, as revealed by ERP slow wave activity, is beneficial for memory performance. In fact, results concerning the relationship between retrieval orientation and memory performance are mixed. One line of evidence speaks in favor of a positive relationship between source memory performance and the retrieval orientation ERP effect (e.g. Bridger et al., 2009; Bridger & Mecklinger, 2012; Rosburg, Johansson, Sprondel, & Mecklinger, 2014). Bridger et al. (2009) compared two types of targeted source information in a memory exclusion task; namely, how easy it would be to draw an object and the generated function of an object. They found statistically reliable ERP effects of retrieval orientation only in the group of participants with high memory performance.

In contrast, Rosburg et al. (2011) did not find a relationship between the retrieval orientation ERP effect and absolute source memory performance (i.e. source discrimination *Pr* score). Instead, they found a correlation with relative task difficulty (i.e. the difference in source memory performance between both tasks). Participants with a large relative difficulty score (i.e. worse performance in the more difficult imagine condition as compared to the perceive condition), showed a larger frontal RO ERP effect. The authors interpreted this result as evidence in favor of a retrieval effort account, in which the high task demands lead to a larger deployment of processing resources for retrieval attempts (Rugg & Wilding, 2000; see also Dzulkifli, Sharpe, & Wilding, 2004).

We argue that the presence of non-target retrieval in memory exclusion tasks can account for the mixed evidence concerning the relationship between the RO ERP effect and memory performance. Critically, the use of non-target retrieval varies between tasks and the reasons for this are not well understood so far. It is either assumed that the amount of non-target retrieval depends on the difficulty of target retrieval (see Herron & Rugg, 2003b) or that non-target retrieval depends on the general accessibility of non-target information (Rosburg, Johansson, & Mecklinger, 2013; see Rosburg & Mecklinger, 2017 for a review). It is also possible, that the occurrence of non-target retrieval also varies with participant's memory capacity. Participants with good memory performance might have the capacity to additionally use non-target retrieval when it is beneficial, which could additionally obscure a relationship between memory performance and retrieval orientation.

Given the mixed pattern of results concerning the impact of non-target retrieval on both, memory performance and the RO ERP effect, the second goal of the current study was to explore the relationship between source memory performance and the RO ERP effect in a task in which effects of non-target retrieval can be completely ruled-out.

2. Material and methods

2.1. Participants

Data from 20 healthy students of Saarland University or pupils (14 female, 6 male, with an age range from 18 to 25, $Mdn = 20.5$ years, $SD = 2.47$) was analyzed in this study. The required sample size of $N = 17$ was determined with a power analysis (G*Power, Version 3.1.9.4.; Faul, Erdfelder, Buchner, & Lang, 2009) for a one-sided paired-samples t-test with $\alpha = 0.05$ and $(1\text{-}\beta) = 0.80$, and Cohen's $dz = 0.66$ (based on visual assessment of the RO ERP effect from 600 to 800 ms in Figure 1 by Rosburg et al. (2011) and by consideration of the study design). This effect corresponds to our main contrast of interest, i.e. the differences in CR ERPs between the label and color condition. Data from six additional participants was excluded due to technical errors ($n = 1$) or chance performance in the source memory task (i.e. source discrimination $Pr \leq 0$ in one or both tasks; $n = 5$). All participants reported being right-handed and German native speakers, having no neurological disorders and normal or corrected-to-normal vision. Participants gave written informed consent and were reimbursed with 8€/h. Participants were debriefed after the experiment.

2.2. Stimulus materials

264 pictures selected from the WSEFEP database (Olszanowski et al., 2015) and a data base created by Minear and Park (2004), consisting of an equal number of older and younger, male and female faces, respectively, were used in this experiment. The experimental stimuli were created in Adobe Photoshop CS6 (Adobe Systems Incorporated). Eye-catching features like jewellery and squinting were removed from the faces and the background color was set to white (R: 255, G: 255, B 255). We created three identical exemplars of each face-identity, differing only in t-shirt color, which was either orange (R: 255, G: 165, B: 0), violet (R: 128, G: 0, B: 128), or black (R: 0, G: 0, B: 0). This colors were chosen as prior ratings indicated that purple and orange have the least affective or semantic connotations (Weigl, 2019; see Weigl, Pham, Mecklinger, & Rosburg, 2020). All stimuli were then re-sized to the same size (620 px × 460 px). Two greyscale logos displaying a vulture (size: 206 × 250 px) for the group of evil people and a dove (size: 250 × 202 px) for the group of good people were created and put in the upper right corner of each face identity (see Fig. 1). The vulture and the dove were selected to illustrate the assignment of the corresponding person to the

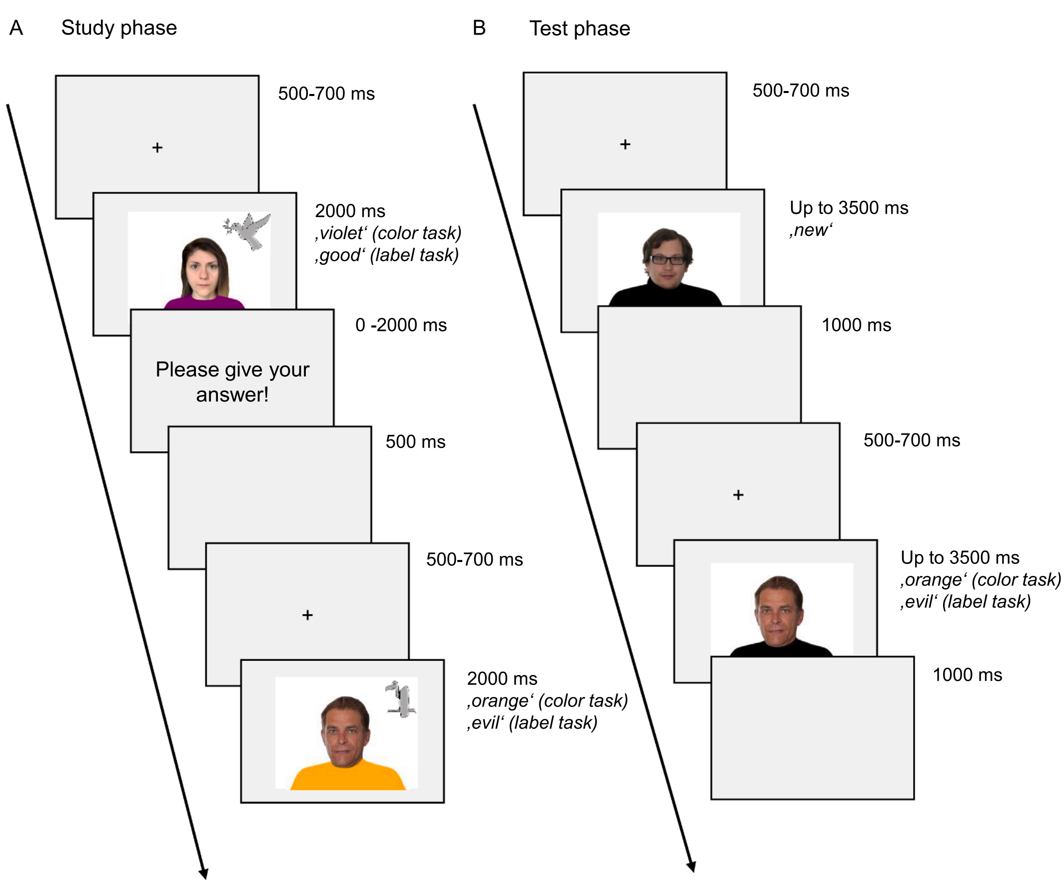

Fig. 1. Trial procedure for study and test phase. The correct answers, depending on the relevant task in the current block, are printed in italics. The images in this figure show the authors of this article. These images were not included in the original stimulus materials.

group of bad (vulture) or good people (dove) in the label task.

Out of the 264 facial identities, the same 256 facial identities were assigned to the main experiment for all participants, whilst the eight remaining faces were used in practice trials. All individuals depicted on the pictures in the main experiment were White; practice trials also included pictures of individuals from other ethnic groups. For the main experiment, the 256 pictures of facial identities were divided into two sets of 128 pictures each.

For each participant, one set was presented as to-be-learned material in the study phase, whilst the remaining set served as distractors in the test phase. Within a set, half of the faces were presented in the color task, whereas the other half was presented in the label task. The order of tasks was counterbalanced across participants and both possible orders occurred equally often. Across all participants, each picture was presented in each possible combination of t-shirt color and label at least once. However, faces were never repeated within participants.

Considering the general difficulty of an associative face memory task, the experiment was broken into two study-test cycles per task (i.e. two study test cycles for the color task and two study-test cycles for the label task), resulting in 4 study-test-cycles in total. Within a study phase, stimulus presentation was random. With regard to the test phase, subsets of 32 new stimuli from the remaining set were assigned to each of the four cycles and this assignment was counterbalanced across participants. Stimulus presentation in the test phase was pseudorandom, i.e. only 5 consecutive trials were allowed to require the same type of response. Within a response type, stimulus presentation was random.

2.3. Procedure

At the start of each session, participants completed questionnaires concerning demographic aspects and general health and the Edinburgh Handedness Inventory (Oldfield, 1971). Next, EEG was applied, and participants were sat in a dimly lit, sound absorbing, and electrically shielded cabin.

The experiment was created using E Prime 2.0 (Psychology Software Tools, Pittsburgh, PA) and presented on a 19-in. monitor with a resolution of 1280 × 1024 px. Viewing distance was approximately 100 cm.

To increase task engagement, the whole experiment was embedded into a larger cover story. Participants were informed that they could gain benefits in a fictive health insurance bonus program. Therefore, they would have to memorize the faces of insurance agents, who are responsible for the approval of their bonus, together with an additional feature. In the t-shirt-color task, this feature was the color of the insurance agent's t-shirt, which was either orange or violet. In the label task, participants were told that there was a group of good individuals, who would most likely approve their bonus and another group of evil individuals, who would most likely not approve their bonus. A label indicated group assignment: a dove identified good persons, whereas a vulture was shown for bad people. For the test phase, participants were told that in order to find a suitable insurance agent, they should try to remember the associated feature for each face from the study phase. The experiment consisted of two larger phases with either t-shirt-color or group assignment being the task-relevant feature. During each phase, participants underwent a short instruction-and-practice phase, followed by two study-test-cycles. Before starting with the study-test-cycles, participants familiarized with the task by completing a complete practice cycle, consisting of 4 study trials and 8 test trials in each task.

During each study phase, participants studied 32 face-feature associations, resulting in a total amount of 64 study trials per task. Each trial had the following structure. First, a jittered fixation cross of a length between 500 and 700 ms was followed by the stimulus display, presented for 2000 ms. The stimulus display always contained a picture of a person with either an orange or violet t-shirt, as well as the label of the dove or vulture, presented in the upper right corner of the picture (see Fig. 1 for the trial procedures of study phase and test phase). In the color task, participants had to focus on the color of the t-shirt and ignore the label. The reverse was true for the label task. Furthermore, participants were instructed to memorize the face-feature associations and indicate the color of the t-shirt (orange or violet) or the group assignment (good or evil) by pressing either the left or the right innermost button on a CEDRUS RB-830 button box (Cedrus Corporation, San Pedro, CA). Key assignment varied across participants, such that each assignment occurred at least once. If participants did not respond within the duration of stimulus presentation, the stimulus was removed from the screen and a prompt asking participants for their answer was presented for additional 2000 ms. The next trial started after a 500 ms blank screen. To avoid recency effects and assure a constant retention interval, the study phase was followed by a short break of approximately 3 min length. During this break, participants watched short video clips with animal documentary videos. Participants were told to concentrate on the videos, as they would be asked something about them later on.

During the test phase, the faces were presented together with a black t-shirt and without the label. Participants now performed a source memory task for the 32 studied faces, together with 32 new faces. Their task was to indicate with which feature they learned the face in the study phase, or if the face was a new face, which was not presented during the study phase. Key assignment (orange, violet in the color task or good, bad in the label task) remained the same as in the study phase, with an additional button for new responses, which was either on the left or right side of the button box. Key assignment for the additional button was counterbalanced across participants. Each trial started with a jittered fixation cross with a length between 500 and 700 ms, followed by the stimulus display. The stimulus remained on the screen until the participant responded, but for a maximum duration of 3500 ms. The next trial started after a 1000 ms blank.

After the last test phase, participants performed an unrelated visual oddball task and completed a questionnaire about the experiment

2.4. Data acquisition and pre-processing

The EEG was continuously recorded from 27 Ag/AgCl scalp electrodes (Fp1, Fp2, F7, F3, Fz, F4, F8, FC5, FC3, FCz, FC4, FC6, T7, C3, Cz, C4, T8, CP3, CPz, CP4, P7, P3, Pz, P4, P8, O1, O2, and M2), attached in an elastic cap (Easycap, Hersching, Germany). Electrodes were arranged following the extended international 10–20 system (Jasper, 1958). BrainVision Recorder 1.0 (Brain Products, Gilching, Germany) was used for data recording. AFz was chosen as ground electrode and the signal was online referenced to the left mastoid electrode. Electroocular activity was assessed via four additional electrodes, placed above and below the right eye and outside the outer canthi of both eyes. All electrode impedances were kept below 5 kΩ, with the exception of the electroocular electrodes' impedances, which were kept below 10 kΩ. Online, data was sampled at 500 Hz and filtered from 0.016 Hz (time constant 10 s) to 250 Hz.

Offline, the data were pre-processed using BrainVision Analyser 2.1. (Brain Products, Gilching, Germany). The data were first scanned for low-activity and filtered, using a zero phase-shift Butterworth bandpass-filter from 0.1 Hz (24 dB/oct) to 30 Hz (48 dB/oct). After removing data from experimental breaks, an independent component analysis (ICA) algorithm was used to correct for ocular, muscular and electrocardic artifacts. A maximum of 5 components was removed per participant. After, data was re-referenced to linked mastoid and segmented into epochs of 2000 ms, including a 200 ms baseline. A baseline correction was applied, followed by a semi-automatic artifact rejection removing segments with amplitudes below −75 or above 75 μV. Average ERPs were then calculated for correct rejections of new items for each task (color and label), respectively. ERPs of correct rejections were based on 42.6 trials (range: 24–61 trials) in the color task and 44.3 trials (range: 25–61 trials) in the label task.

2.5. Data analysis

For all analyses, the significance criterion of $p < .05$ was applied. Data were analyzed using IBM SPSS statistics (version 26, IBM Corporation).

2.6. Behavioral data analysis

Similar to Rosburg et al. (2011), source discrimination *PrS* was calculated for each task (color and label) separately. *PrS* was calculated as the difference between source hit rates (p[target hit]) in the arbitrarily defined target distribution (orange for the color task, good for the label task) and source false alarm (FA) rates (p[target false alarm]) in the resulting non-target distribution (violet in the color task and evil in the label task; see Mollison & Curran, 2012) for each participant. The rate of correctly rejected items (CRs, p[correct rejection]) is reported for each task, separately.

Additionally, mean reaction times for correct responses were calculated for each task and response type separately. Paired-samples t-tests were used to compare the source discrimination measures *PrS* across tasks. One person was excluded from this analysis as an outlier (z-score > 3). To analyze reaction times, a repeated measures MANOVA with the within-participant factors response type (source hit, source FA and CR) and task (color, label) was calculated and Pillai's trace is reported. Significant effects were further explored in follow-up paired-samples t-tests. Whenever non-hypothesis-driven multiple testing was required, the Bonferroni-Holm correction (Holm, 1979) was applied. The reported corrected p-values were calculated with the function p.adjust of the R package stats (RStudio version 1.2.5001, R version 3.6.1, R Core Team, 2019). As measure of effect size, we report Cohen's d for effects from t-tests. As Pillai's trace is reported for effects from MANOVAs, values of partial eta-squared ($\eta 2$) are omitted to avoid redundancy.

2.7. ERP data analysis

Mean amplitudes were separately quantified for correct rejections in the label task and the color task for the preselected time-window of 600–800 ms. All stimulus-locked analyses were restricted to this time window and calculated for a subset of electrodes, namely F3, Fz, F4, C3, Cz, C4, P3, Pz, P4, as they cover the main sites of interest.

As sphericity is usually violated in EEG data, we used the multivariate approach of repeated measure ANOVA (MANOVA), which is it is more robust against such violations of sphericity (Dien & Santuzzi, 2005; Picton et al., 2000), to assure validity of results. Initial analyses for the effects of retrieval orientation included a global MANOVA with the factors anteriority (frontal, central, posterior), laterality (left, middle, right) and task (color, label) and Pillai's trace is reported. For the sake of readability, we only report significant effects.

In order to explore the relationship between the ERP correlates of retrieval orientation and relative difficulty between tasks in memory performance, we calculated difference ERPs by subtracting ERP scores on correct rejections in the color task from ERP scores on correct rejections in the label task, resulting in a relative retrieval orientation effect (ΔERP).

Additionally, we calculated relative difficulty between tasks in memory performance by subtracting *PrS* in the color task from *PrS* in the label task (ΔPrS). Mean source discrimination performance of both tasks ($\overline{PrS}$) was also calculated.

Pearson correlations between ΔERP at electrode F3, where the RO ERP effect was largest, and ΔPrS were calculated, as well as between ΔERP and mean source discrimination performance ($\overline{PrS}$). Additional task-specific correlational analyses were calculated between ΔERP and *PrS* for each task, respectively. Data inserted into the correlational analyses were screened for bivariate outliers using standardized residuals in the corresponding regression model. One participant with a z-score above 2.58 was excluded from the correlational analysis between ΔERP and $\overline{PrS}$, as well as from both task-specific correlational analyses.

3. Results

3.1. Behavioral results

Table 1 shows the behavioral performance data. Source discrimination as measured with *PrS* was better in the label task than in the color task, $t(18) = 4.65$, $p < .001$, $d = 1.08$. We used t-tests with a Bonferroni-Holm-corrected significance level to compare source hit rates, source FA rates and CR rates across tasks. Whilst there was a significant difference between source hit rates across tasks, $t(18) = 2.85$, $p = .033$, $d = 0.65$, there was no such difference between source FA rates, $t(18) = 1.93$, $p = .140$, $d = 0.44$ or CR rates, $t(18) = 1.57$, $p = .140$, $d = 0.36$.

Table 2 shows reaction time data per task and type. A repeated measures MANOVA on reaction times with the factors response type (source hit, source FA and CR) and task (color, label) revealed a significant main effect of response type, Pillai's trace = 0.63, $F(2, 18) = 15.27$, $p < .001$, as well as a significant interaction between response type and task, Pillai's trace = 0.34, $F(2, 18) = 4.54$, $p = .025$. Bonferroni-Holm-corrected post-hoc comparisons, calculated separately for each response type across tasks, showed no significant results ($p > .912$). We compared the different response types, averaged across tasks, by using t-tests, again with a Bonferroni-Holm-corrected significance level. Participants were faster in making correct rejections than source hits, $t(19) = 5.18$, $p < .001$, $d = 1.16$ and source FAs, $t(19) = 5.68$, $p < .001$, $d = 1.27$, whereas there was no difference between source hits and source FAs, $t(19) = 1.75$, $p = .096$, $d = 0.39$.

3.2. Electrophysiological results

Fig. 2 depicts the grand average ERPs elicited by correctly rejected new faces in the test phase, for each task separately. ERPs significantly diverge at approximately 600 ms to 800 ms after stimulus onset, with ERPs in the label task being more positive than ERPs in the color task. This effect was largest at electrode F3.

This visual impression was corroborated by the MANOVA for effects of retrieval orientation. The MANOVA revealed a significant main effect of anteriority, Pillai's trace = 0.74, $F(2, 18) = 25.46$, $p < .001$, a significant anteriority by laterality interaction, Pillai's trace = 0.69, $F(4, 16) = 9.06$, $p = .001$ and, as predicted, a significant three-way interaction of anteriority, laterality and task, Pillai's trace = 0.61, $F(4, 16) = 6.15$, $p = .003$. To dissolve the three-way interaction of anteriority, laterality and task, separate planned t-tests were calculated for each electrode above the averaged time window of 600–800 ms. Those yielded the predicted difference at electrode F3 in that ERPs in the label task were more positive than ERPs in the color task (5.47 μV *SD* 6.38 μV vs. 4.15 μV *SD* 5.80 μV, $t(19) = 1.73$, $p = .050$, $d = 0.39$, one-sided). No other comparison approached significance.

Next, correlational analyses were performed between the mean amplitude of retrieval orientation at electrode F3 in the time window from 600 to 800 ms (ΔERP) and the behavioral measures relative difficulty ΔPrS, as well as mean source discrimination performance ($\overline{PrS}$).

There was no significant relationship between relative task difficulty

Table 1
Memory performance measures for each task.

	Color task	Label task
Source Hit rate	0.45 (*SD* 0.09)	0.54 (*SD* 0.09)
Source FA rate	0.28 (*SD* 0.11)	0.25 (*SD* 0.11)
PrS	0.17 (*SD* 0.09)	0.29 (*SD* 0.14)
CR rate	0.70 (*SD*.16)	0.74 (*SD* 0.12)

Note. FA = false alarm, *PrS* = source discrimination *Pr* score, CR = correct rejection.

Table 2
Reaction times in ms per task and memory response type.

	Color task	Label task
Source Hit	1516 (*SD* 364)	1530 (*SD* 317)
Source FA	1520 (*SD* 384)	1596 (*SD* 293)
CR	1275 (*SD* 290)	1263 (*SD* 315)

Note. FA = false alarm, CR = correct rejection.

and ΔERP at electrode F3, $r = 0.14$, $p = .557$, two-sided. However, there was a significant relationship between ΔERP at electrode F3 in this time window and mean source discrimination performance, $r = 0.55$, $p = .015$, two-sided, which can be seen in Fig. 3. Bonferroni-Holm corrected, task-specific correlational analyses show both a significant correlation of the RO ERP effect and source memory performance in the color task ($r = 0.478$, $p = .038$, two-sided) and in the label task ($r = 0.533$, $p = .038$, two-sided), with a larger RO ERP effect being related to better source memory performance in the respective task.

To sum up, effects of retrieval orientation can be found from 600 to 800 ms, stimulus-locked at electrode F3, with more positive amplitudes

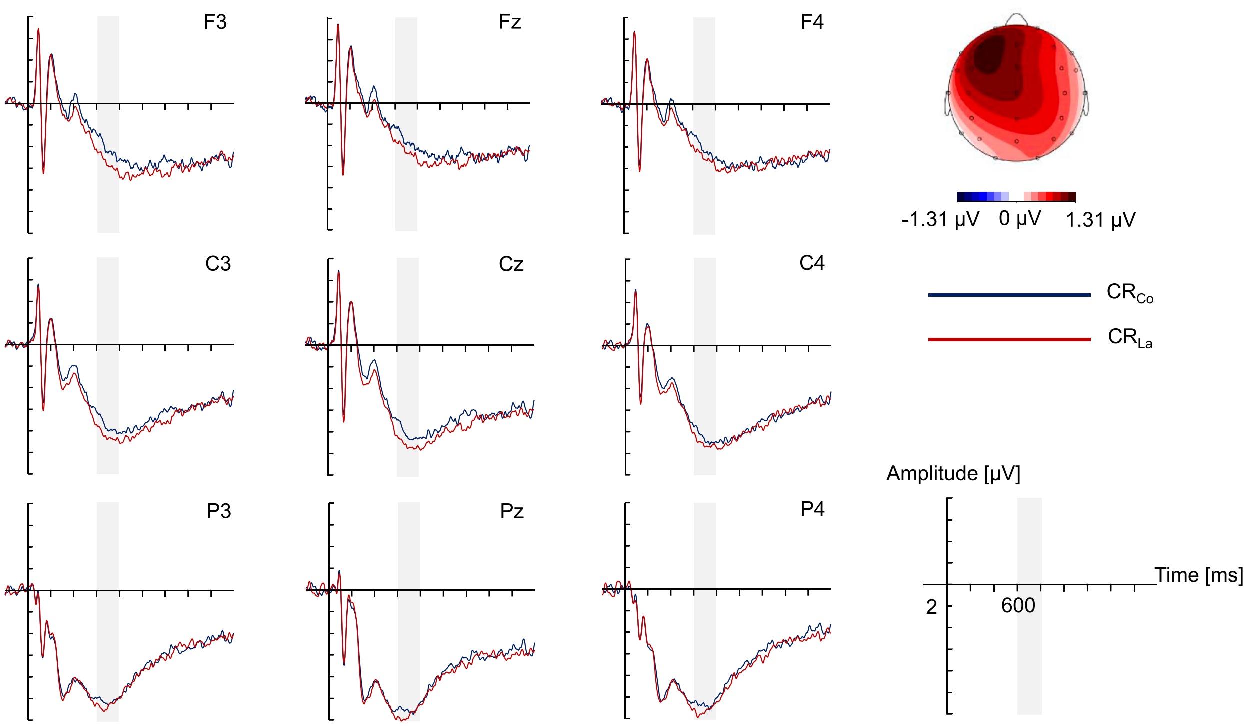

Fig. 2. Event-related potentials of retrieval orientation. Correct rejections in the color task (CR_{Co}) are depicted in blue, correct rejections in the label task (Cr_{La}) are depicted in red. The grey bar represents the analyzed time window from 600 to 800 ms. The topographic map displays the RO ERP effect in the analyzed time window from 600 to 800 ms. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

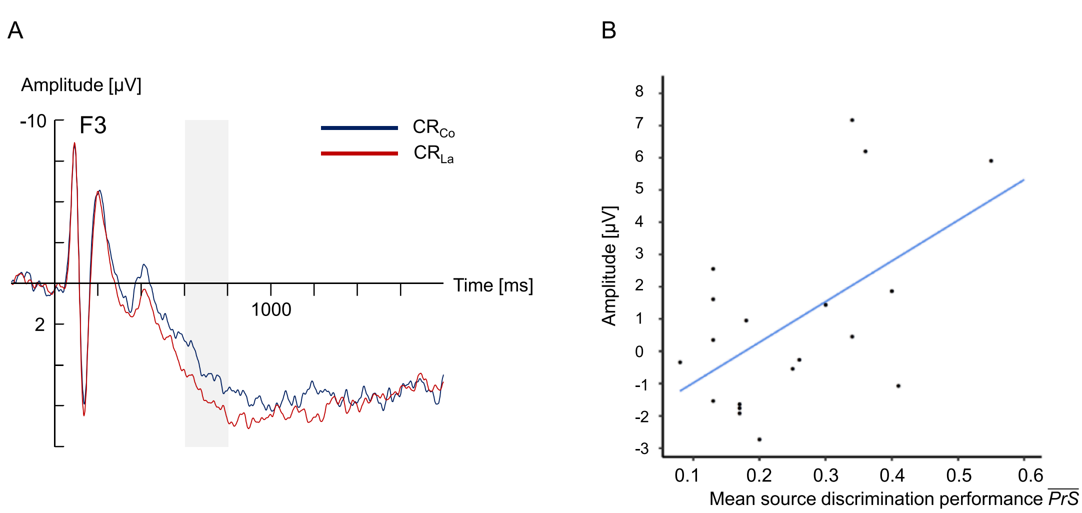

Fig. 3. Correlation between the RO ERP effect and source memory performance. Panel A: Event-related potentials elicited by correct rejections in the color task (blue line) and in the label task (red line) at left frontal electrode F3. The grey bar marks the analyzed time window from 600 to 800 ms after stimulus onset. Panel B: The scatterplot shows the correlation between the RO ERP effect and the averaged source memory measure $\overline{PrS}$. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

in the label task compared to the color task. Further, this effect is associated with mean source discrimination performance of both tasks, as well as source discrimination performance for each task, separately, with larger retrieval orientation ERP effects going hand in hand with larger source discrimination performance.

4. Discussion

We pursued two goals with the current study. Firstly, we aimed to conceptually replicate the frontal RO ERP effect by Rosburg et al. (2011), reflecting strategic retrieval processing, initiated to recover self-relevant, as compared to less self-relevant information from memory. Critically, we argued that possible confounds due to non-target retrieval in memory exclusion tasks impede a functional interpretation of the RO ERP effect. Therefore, non-target retrieval effects were prevented in the current task setting by the use of a source memory task that disables responses based on inference (i.e. detecting targets by using non-target information) between compared source types. Secondly, we aimed to explore the relationship between the RO ERP effect and source memory performance in this setting. This aim was motivated by the idea that individual differences in the use of retrieval strategies in memory exclusion tasks, like non-target retrieval, also contribute to the mixed evidence concerning the relationship between the RO ERP effect and source memory performance (e.g. Bridger & Mecklinger, 2012; Rosburg et al., 2011).

Behaviorally, we found better source memory performance in the label task, as compared to the color task, while there was no difference in reaction times across tasks. More important, we found the expected RO ERP effect with more positive-going waveforms for correct rejections in the label task, compared to the color task, in the time-window from 600 to 800 ms with a left frontal topographical focus. Thus, we achieved our goal of a conceptual replication of the frontal RO ERP effect from the study by Rosburg et al. (2011). Concerning our second goal, we found a positive relationship between the RO ERP effect and source memory performance in both tasks, whereas we did not observe a relationship between the frontal RO ERP effect and retrieval effort, operationalized as the difference between source memory performance in the label task and source memory performance in the color task. This pattern of results supports the view of a positive relationship between the RO ERP effect and memory performance when effects of non-target retrieval are avoided (Bridger & Mecklinger, 2012).

4.1. Behavioral results

In the current study, there was a behavioral source memory advantage for the more self-relevant label task, compared to the color task. This is in contrast to the study by Rosburg et al. (2011), in which source discrimination performance was better in the less self-relevant perceive condition, as compared to the more self-relevant imagine condition. However, as argued by Rosburg et al. (2013), the experimental conditions in this study also differed in the amount of pictorial information included in the stimuli, as a picture was presented in the perceive condition, but was to be mentally created in the imagine condition. Consequently, a picture superiority effect (Paivio, Rogers, & Smythe, 1968) could account for this contradicting pattern of results. As in the current study, the stimuli were identical in both tasks, the source memory differences between both tasks cannot be accounted for by a picture superiority effect.

We assumed that the label task, but not the color task, would require the retrieval of self-relevant information, induced by the detailed and semantically rich cover story. Information which is processed in relation to one's self shows a memory advantage over otherwise semantically processed information (Kelley et al., 2002; Rogers, Kuiper, & Kirker, 1977). The high self-relevance of the memory contents in the label tasks may have led to deeper encoding and thus richer and multi-facetted memory traces (see Craik & Lockhart, 1972). This in turn might render memory traces of the label task more readily accessible than the corresponding memory traces in the color task, accounting for the memory advantage in the label task.

4.2. The frontal RO ERP effect

As outlined in the introduction, memory exclusion tasks permit participants to successfully solve the task without adopting a retrieval orientation that includes retrieving non-target information. By using a source memory task, we avoided any possibility of inference from non-target retrieval, which might attenuate or modify RO ERP effects (Bridger et al., 2009). In line with the study of Rosburg et al. (2011), we found an effect of retrieval orientation at electrode F3 in the same time-window (from 600 to 800 ms after stimulus onset), with more positive amplitudes in the label task, associated with self-relevant information, compared to the color task. As participants could not make use of non-target retrieval or indirect conclusions via task-irrelevant information in the current task setting, we assume that this frontal RO ERP effect reflects a pure measure of the adoption of a retrieval orientation for self-relevant memory contents.

As outlined in the introduction, by asking participants to focus on either perceptual or conceptual features of the study phase, our study entails a manipulation of encoding focus. Previous studies, investigating effects of encoding focus on test phase ERPs, consistently report that encoding focus primarily affects ERPs elicited by hits and could reflect the type or amount of features bound in memory or the amount of reconstructive processing of retrieval outcomes (Leynes & Mok, 2017; Leynes & Nagovsky, 2016). As these studies did not find any effect of encoding focus, neither on correct rejections, presumably because these items were not processed in the encoding phase, nor on ERPs to correct rejections indicative of retrieval orientation, we feel safe to conclude that our effects do reflect the adaptation of task specific retrieval orientations.

Concerning a functional interpretation of the frontal RO ERP effect, we propose that the frontal RO ERP effect is associated with searching for self-relevant information in general and is not restricted to visually or auditory imagined information (Leynes et al., 2005; Rosburg et al., 2011). In the current study, a group assignment task of character information was used, in which participants could base their source memory decision on recovered self-relevant information. In contrast, the critical feature in the color task is perceptual and can hardly be processed semantically. Therefore, self-relevance in this condition is low. The frontal RO ERP effect resembles retrieval orientation ERP effects in two other studies, in which frontal ERPs were more positive when self-relevant information was targeted. Johnson, Kounios, and Nolde (1997) found more positive frontal ERPs to new items in a retrieval condition in which participants had to indicate how many functions they could generate for a given item and Herron and Wilding (2004) found more positive frontal RO effects for a target condition in which participants rated the pleasantness or animacy of items. To our knowledge, there are no studies in which the RO ERP effect for self-relevant information is investigated directly.

However, if the frontal RO ERP effect reflects the processing of self-relevant information, it should resemble ERP effects in other memory studies exploring the encoding or retrieval of self-referential information in its time course, topography and polarity. In support of this view, Magno and Allan (2007) explored the retrieval of self-referential general and episodic information and reported late (>800 ms) ERP positivities with largest amplitudes at frontal recording sites. Mu and Han (2010) investigated self-referential processing by using a trait judgment task and found that self-referential trait judgments, relative to other referential traits, induced enhanced theta activity over frontal areas between 700 and 800 ms, a time window which is highly similar to the time window in which the RO effects was largest in the present study. Fields and Kuperberg (2012) used short discourse scenarios to explore ERP correlates of self-relevance and emotion. Effects of self-relevance (larger positivities for self-relevance than for other relevance) were obtained in a late time interval (500–800 ms) at frontal recording sites.

These studies support our view that the present RO effects reflects the adaptation of a retrieval orientation, that supports the retrieval of self-relevant information. Even though different operational definitions for self-relevance were used, they also suggest that self-referential processing is associated with a common neural signature and the anterior focus of the reported ERP/EEG effects is well in line with evidence from brain-imaging studies, that self-referential processing is related to the medial prefrontal cortex (mPFC; Kelley et al., 2002; Macrae, Moran, Heatherton, Banfield, & Kelley, 2004).

An interesting question that arises is what exact aspect of self-relevance drives the frontal RO ERP effect. As the label task of the current study includes emotionally loaded stimuli, the topography of the RO ERP effect in the current study could also be explained by emotional processing, as neural correlates of emotional memory also have been found at left frontal sites (Sergerie, Lepage, & Armony, 2005). Of note, not all studies observing the frontal RO ERP effect involve emotional processing (e.g. Leynes et al., 2005; Rosburg et al., 2011), which makes it unlikely that emotional processing is the only source of the frontal RO ERP effect. Interestingly, emotional processing has been argued to share processes with self-referential processing, accounting for respective memory benefits (Gutchess & Kensinger, 2018). It might be these overlapping processes that are reflected in the frontal RO ERP effect.

In summary, the frontal RO ERP effect of the present study fits well with a self-relevance account. Future investigations should seek to disentangle the contribution of emotional relevance and self-reference to the frontal RO ERP effect. By using a similar task setting to the current study, this could also shed light on the exact nature of the behavioral memory advantage for the label task compared to the color task.

4.3. The RO ERP effect and memory performance

Our second goal was to explore the relationship between the retrieval orientation ERP effect and source memory performance in a source memory setting, in which confounding strategic effects of the memory exclusion task and certain source memory tasks can be ruled out.

In contrast to the investigations by Rosburg et al. (2011) and Rosburg et al. (2013) and in line with studies by Bridger et al. (2009) and Bridger and Mecklinger (2012), we found a positive relationship between the RO ERP effect and mean source memory performance across both tasks. Better source memory performance was associated with a larger (i.e. larger difference between both tasks) RO ERP effect. We did not observe a relationship between the frontal RO ERP effect and retrieval effort, operationalized as the difference between source memory performance in the label task and source memory performance in the color task. In our opinion, mixed results of previous studies can be explained by the presence of selective non-target retrieval in the memory exclusion task.

We argued that in the current source memory setting, participants naturally have to adopt and tonically maintain a retrieval orientation, as for each task, they have to search within this type of source information and to recover task-specific details in order to give a correct answer. We therefore interpret our results as evidence in favor of a positive relationship between the frontal RO ERP effect and source memory performance.

This is in line with the findings by Bridger et al. (2009) and Bridger and Mecklinger (2012), showing a positive relationship between the retrieval orientation ERP effect and source memory performance in exclusion tasks. Of note, Evans and Herron (2019) published a further study, supporting the positive relationship between the adoption of a retrieval orientation and memory performance. They measured retrieval orientation in the ERP elicited by a retrieval cue preceding the stimulus, which indicated the to-be-retrieved information type in the current trial and found a greater negativity for subsequent source hits as compared to subsequent source memory errors. Despite methodological differences to the present study, the latter findings support the view of a positive relationship between RO ERP effects and memory performance.

Of note, the present findings extend previous results (Bridger & Mecklinger, 2012; Bridger et al., 2009; Rosburg et al., 2014) regarding the question of how exactly retrieval orientations influence memory performance in an important way. In previous studies on retrieval orientation and memory performance (Bridger & Mecklinger, 2012; Bridger et al., 2009; Rosburg et al., 2014), successful source memory performance required the discrimination between different source types (i.e. the difference that is reflected in the RO ERP effect). Critically, source memory is assumed to comprise a decision process, based on the evaluation of several memory records (Johnson et al., 1993). It thus remains unclear whether the adoption of a retrieval orientation benefits the retrieval of underlying associations or processes of weighting and evaluating these retrieved associations to make a source decision. If retrieval orientation supports the retrieval of associations, beneficial effects of retrieval orientation on memory performance should not be restricted to source memory tasks with high demands in decision processes. In the color task of the current study, recovering the studied single face-feature association suffices to give a response. Interestingly, the RO ERP effect was related to memory performance collapsed across both tasks and also to source memory performance in each task, separately. This positive relationship between the RO ERP effect and source memory performance in both tasks thus implies that retrieval orientations do not only act at the level of evaluation and decision processes ('the insurance agent was rude'), but also benefit the recovery of the actually underlying single associations ('the last time, the insurance agent hit the table').

5. Conclusion

Taken together, the current study both adds to evidence that retrieval orientation is beneficial for source memory performance and extends previous results by providing insights into how retrieval orientation imposes its influence on memory performance. Critically, we argued that the often-used memory exclusion task enables non-target retrieval, which might confound ERP correlates of retrieval orientation and its relationship to source memory performance.

In a source memory task avoiding such confounding effects, we found a frontal RO ERP effect, which closely resembles the RO ERP effect in (Rosburg et al., 2011), which we interpret as reflecting the search for self-relevant information. In contrast to this latter study, a larger RO ERP effect in the current study is related to better source memory performance in both tasks. This pattern is in line with the other previous findings, showing a positive relationship between the retrieval orientation ERP effect and source memory performance in exclusion tasks. Differing effects of non-target retrieval might account for contradicting evidence on this topic in the above-mentioned studies.

Lastly, the frontal RO ERP effect is also related to source memory performance in the merely perceptual color task. This pattern was interpreted as evidence that retrieval orientations do not only act on the level of evaluation and decision processes, but also benefit the recovery of the actually underlying single associations.

CRediT authorship contribution statement

Julia A. Meßmer: Conceptualization, Methodology, Software, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration. **Michael Weigl:** Formal analysis, Resources, Writing - review & editing. **Juan Li:** Conceptualization, Writing - review & editing. **Axel Mecklinger:** Conceptualization, Methodology, Writing - review & editing, Supervision, Project administration, Funding acquisition.

Declaration of Competing Interest

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

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