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Retrieving self-vocalized information: An event-related potential (ERP) study on the effect of retrieval orientation

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ABSTRACT

Retrieval orientation refers to a pre-retrieval process and conceptualizes the specific form of processing that is applied to a retrieval cue. In the current event-related potential (ERP) study, we sought to find evidence for an involvement of the auditory cortex when subjects attempt to retrieve vocalized information, and hypothesized that adopting retrieval orientation would be beneficial for retrieval accuracy. During study, participants saw object words that they subsequently vocalized or visually imagined. At test, participants had to identify object names of one study condition as targets and to reject object names of the second condition together with new items. Target category switched after half of the test trials. Behaviorally, participants responded less accurately and more slowly to targets of the vocalize condition than to targets of the imagine condition. ERPs to new items varied at a single left electrode (T7) between 500 and 800 ms, indicating a moderate retrieval orientation effect in the subject group as a whole. However, whereas the effect was strongly pronounced in participants with high retrieval accuracy, it was absent in participants with low retrieval accuracy. A current source density (CSD) mapping of the retrieval orientation effect indicated a source over left temporal regions. Independently from retrieval accuracy, the ERP retrieval orientation effect was surprisingly also modulated by test order. Findings are suggestive for an involvement of the auditory cortex in retrieval attempts of vocalized information and confirm that adopting retrieval orientation is potentially beneficial for retrieval accuracy. The effects of test order on retrieval-related processes might reflect a stronger focus on the newness of items in the more difficult test condition when participants started with this condition.

1. Introduction

Women and men have been reported to use on average 16,000 words a day (Mehl, Vazire, Ramírez-Esparza, Slachter, & Pennebaker, 2007). Given this large amount, it is little surprising that we experience situations in everyday life in which we cannot remember whether we actually said something or just had the intention to do it, and this might cause irritations. Imagine you had the intention to ask, but actually forgot asking your partner to get a package of coffee while shopping. Later on, you erroneously believe that you asked your partner because you vividly remember the intention of asking her/him. This little memory lapse might create a situation on the next day where you have breakfast without coffee but with some distressing argument instead.

In general, episodes (e.g. in form of intentions or actions) can be remembered voluntarily or involuntarily when one encounters an appropriate cue (Richardson-Klavehn & Gardiner, 1995). When having coffee the day after the argument, you might involuntarily remember the bizarre scene at the breakfast table. In goal-directed behavior, however, episodic information is often retrieved by volition. Such voluntary retrieval can sometimes interact with involuntary retrieval and be disturbed by it, for example in form of intrusion errors (Wickelgren, 1965); in other cases, a rememberer might take advantage of incidental recollection when differentiating between target and nontarget information (Rosburg, Mecklinger, & Johansson, 2011b).

Tulving (1983) proposed that a pre-requisite for voluntary recollection is that the rememberer enters an episodic retrieval mode. This retrieval mode has been conceptualized as a state in which the rememberer treats information as potential retrieval cues for past events (Lepage, Ghaffar, Nyberg, & Tulving, 2000). In refinement of

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this concept, the processing of retrieval cues has been proposed to vary depending on the nature of the to-be-retrieved information or depending on the task requirements (Rugg & Wilding, 2000). This specific form of cue processing has been labeled as retrieval orientation. It is assumed to affect the processing of all test probes, i.e. both old and new items. However, studies on retrieval orientation usually focus on cortical responses to new items, because processing of new items is assumed to be unaffected by retrieval success. Therefore, retrieval orientation is usually determined by contrasting ERPs to new items across tasks with distinct episodic retrieval requirements.

The current event-related potential (ERP) study aimed at investigating retrieval orientation processes when self-vocalized material is targeted. ERPs can provide valuable information about the time course of retrieval orientation effects, due to their high temporal resolution. In addition, the scalp topography of ERP retrieval orientation effects is to some extent informative about the underlying cortical generators. In our current study, we sought to reveal whether targeting self-vocalized material would result in an ERP retrieval orientation effect consistent with the notion of an activation of auditory cortices. For this purpose, we calculated current source density (CSD) maps (Perrin, Bertrand, & Pernier, 1987; Perrin, Pernier, Bertrand, & Echallier, 1989), since CSD maps are more informative about underlying generators than conventional scalp maps (Srinivasan, 2005). We expected an involvement of the auditory cortices in such retrieval attempts on the basis that (a) retrieval orientation processes have been suggested to directly operate on the level of memory representations ('target bias', Dzulkifli & Wilding, 2005), and that (b) retrieval of prior episodes is supposed to involve the reinstatement of processes or representations that were active when these episodes were encoded ('reinstatement hypothesis', Rugg, Johnson, Park, & Uncapher, 2008). There is indeed some initial evidence by an fMRI study that retrieval orientation can be associated with an activation of modality-specific brain regions (Hornberger, Rugg, & Henson, 2006a). In this study, it was shown that attempts of retrieving words presented auditorily at study produced greater activity in the auditory cortex than attempts to retrieve words that were encoded as pictures, whereas a reversed pattern was found in the fusiform cortex.

Aside from the perceptual format at study, retrieval cue processing varies as a function of cue–target overlap. Previous retrieval orientation studies showed more negative ERPs to new items in conditions that were characterized by incongruent study and test formats (e.g. pictures and words), as compared to conditions in which study and test formats were the same (Halsband, Ferdinand, Bridger, & Mecklinger, 2012; Herron & Rugg, 2003; Hornberger, Morcom, & Rugg, 2004; Robb & Rugg, 2002; Stenberg, Johansson, & Rosén, 2006). It has been suggested that the more negative ERPs in case of study-test incongruence reflect processing differences necessary to maximize overlap between cue and memory representations; in particular, the differential reliance on semantic/conceptual information derived from retrieval cues was proposed to play a major role (Hornberger et al., 2004). According to Hornberger et al. (2004), differences in the need to constrain cue processing to semantic information in case of incongruent study and test formats might be the origin of the described ERP effects in such studies. However, the before mentioned fMRI study of Hornberger et al. (2006a) did not support the notion of constrained cue processing, as no brain regions associated with semantic processing were more active when pictorial items had to be retrieved on the presentation of visual word cues, as contrasted to the retrieval of auditory words.

Previous ERP studies have not systematically investigated the involvement of sensory cortices in retrieval orientation, although some studies contrasted attempts to retrieve auditorily encoded words with attempts to retrieve words that were encoded as pictures (Hornberger, Rugg, & Henson, 2006b; Hornberger et al., 2004). These studies showed more positive going ERPs for retrieval attempts of auditorily encoded words. However, it is not clear whether these differences refer to a differential pattern of reinstatement processes for auditory words and pictures (Hornberger et al., 2006b), or whether these ERP differences can be explained by the relatively greater constraints in cue processing to semantic information when pictorial material was tested (Hornberger et al., 2004). This problem in interpreting the data arose because the primary scope of these studies was to vary the cue–target overlap (rather than only the study format).

To our knowledge, self-vocalized material has been used only in a single ERP retrieval orientation study (Leynes, Cairns, & Crawford, 2005). This study comprised a reality monitoring and an external source monitoring task. At study, participants heard words spoken either by a male or female voice (external source monitoring task), or participants heard words spoken by a male voice or participants generated and vocalized the words themselves (reality monitoring task). The ERPs to new items were contrasted between the two subsequently performed source memory tasks. The authors found more positive ERP deflections at frontal electrode sites between 1000 and 1200 ms for new items in the reality monitoring condition, as compared to the external source monitoring condition. The study is informative about a possible frontal contribution to retrieval orientation in reality monitoring (as also investigated by Rosburg, Mecklinger, and Johansson (2011a); Rosburg, Johansson, and Mecklinger (2013)). However, the study had only a limited sensitivity to inform about the possible contribution of the auditory cortex in attempts to retrieve material that the rememberer previously vocalized because all study conditions included auditory words.

In the current study, we sought to circumvent the problem of incongruent study and test formats, which represented a confounding factor in the Hornberger et al. (2004) data. In the study phase, object words were visually presented and participants subsequently had to vocalize them or had to imagine a picture of the denoted object. At test, object words were again visually presented as cues and retrieval orientation was manipulated by instructing the participants to target either the imagined or the vocalized object words in separate memory exclusion tasks (Jacoby, 1991) (Fig. 1). By this, format was held constant across study and test and participants could be tested under both target designations, with the order of these two tests being counterbalanced across participants.

In detail, the current study had three aims: (1) As outlined, we sought to investigate the time course of the ERP correlate of a retrieval orientation toward vocalized material and to reveal evidence that such retrieval attempts are associated with activation of the auditory cortex. (2) We aimed to assess whether adopting retrieval orientation is beneficial for retrieval accuracy, as suggested by some previous studies (Bridger, Herron, Elward, & Wilding, 2009; Bridger & Mecklinger, 2012; Sprondel, Kipp, & Mecklinger, 2013). We have previously argued that such a positive relationship between retrieval accuracy and retrieval orientation is most likely to be observed when the two kinds of target information are dissimilar and, in consequence, selective activation and inhibition of target representations are possible (Rosburg et al., 2011a). In the current study, we expected that retrieval orientation effects would be primarily present in participants with high retrieval accuracy since the episodic information encoded in both study tasks (visual and auditory) is considerably dissimilar. For evaluating the association between retrieval accuracy and ERP retrieval orientation effects, test order was taken into account in order to assess whether it had an impact on either of them. (3) We aimed to analyze the role of nontarget retrieval in each of the two memory tasks. A prerequisite for the observation of retrieval orientation effects is that the retrieval of

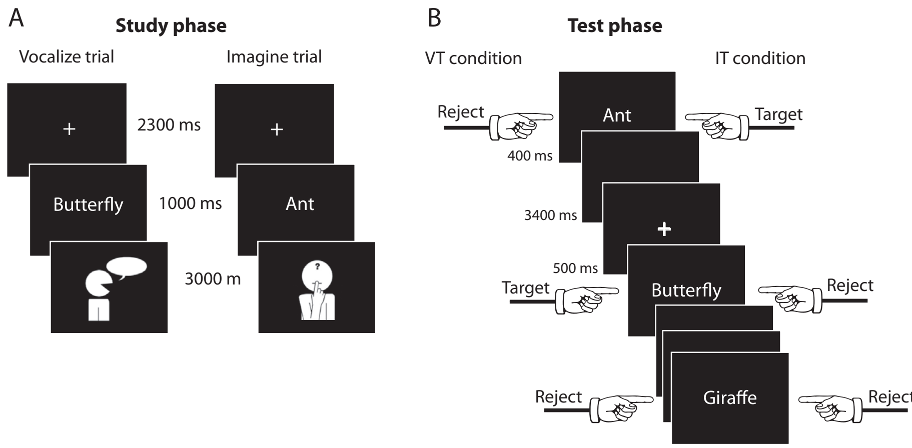

Fig. 1. Schematic view of the experiment: during the study phase (A), concrete object words were presented either in imagine or vocalize trials. In vocalize trials, participants had to name the written word aloud ('spoken words'). In imagine trials, participants had to imagine a picture of the denoted object ('imagined words'). Participants were informed that both vocalizing and imagining would be beneficial for later memory performance. They were, however, explicitly instructed to avoid imagining objects to be vocalized and vocalizing object names to be imagined. (B) After the study phase, participants were tested in a memory exclusion task in which participants were asked either to identify imagined items and to reject spoken items as well as newly presented items as nontargets (IT condition) or to identify spoken items and to reject imagined items as well as new items (VT condition). Half of the studied items were presented in each condition. The order of the two test conditions was balanced across participants. Each studied item was presented only once at test, either as target or nontarget.

target information is prioritized over the retrieval of nontarget information in at least one condition: When participants retrieve target and nontarget information in both test conditions, cognitive processes in the service of retrieval attempts can be expected to be highly similar in both of them and ERP responses to new items do not differ (Dzulkifli, Herron, & Wilding, 2006). Herron and Rugg (2003) suggested that nontarget retrieval becomes more likely with the increasing difficulty of retrieving the target information. Therefore, we expected that in the more difficult test condition participants would take advantage of a recall-to-reject strategy (Clark, 1992) and retrieve nontarget information. Pilot data indicated that retrieval accuracy was considerably lower when vocalized items were designated as targets than when imagined items were targeted. Nontarget retrieval was assessed by quantifying the left-parietal old/new effect, the putative correlate of recollection (Rugg et al., 1998; Smith, 1993; Wilding, 2000).

2. Methods

2.1. Participants

Thirty-two volunteers (16 female), ranging in age from 18 to 29 years (mean age 23 years) took part in the experiment. All participants were students at Saarland University and reported to be of good health with no history of neurological illness. Only German native speakers were included. All participants were right handed and all had normal or corrected-to-normal vision. Data of another 6 participants were discarded due to excessive artifacts during recordings ($n = 2$), incompliance to test instruction ($n = 1$), or poor performance in any of the critical test conditions ($n = 3$), resulting in a too small number of trials for calculating the ERPs. Participants were informed about the procedure of the experiment and gave written consent for participation. Participation was compensated with 8 €/hour or with course credit.

2.2. Experimental procedure

The experiment comprised two blocks consisting of a study and test phase each, as illustrated in Fig. 1: during the study phases, German object names were presented. The name was followed by an icon, indicating the study task. In the speak condition, participants were requested to vocalize the object name aloud. In the imagine condition, participants had to mentally imagine a picture of the denoted object. Trials of the two study conditions occurred in random order, with the restriction that a maximum of three trials of the same condition occurred in succession. Trials started with the presentation of a fixation cross for 2300 ms. Thereafter, single object words were presented for 1000 ms. Two different icons indicated which task the participants had to perform. Icons remained on the screen for 3000 ms. After a short pause (blank screen for 500 ms), the next trial started. Participants were informed that the study phase was followed by a recognition test, but without qualifying its exact nature. However, they were encouraged to pay full attention to the study tasks, because this would also support their recognition performance later on. Furthermore, instruction stressed that the participants should not vocalize items to-be-imagined and should not imagine items to-be-vocalized in order to avoid confusions.

Participants were tested in a memory exclusion task with the target category switching after half of the trials in each of the two test blocks: In the imagined item target (IT) condition, participants had to identify object names that had been presented in the imagine condition (targets) and to reject object names of the speak condition (nontargets) together with new object names. In the spoken item target (VT) condition, participants had to identify object names that had been presented in the speak condition and to reject object names of the imagine condition together with newly presented object names. As illustrated in Fig. 1, cue presentation did not differ between the two test conditions. Participants were instructed to respond as fast and accurately as possible. In the test phase, trials started with a fixation cross, lasting for 500 ms. Object names were presented for 400 ms. There was a time limitation of 3400 ms for giving a response. Participants responded by pressing the letters "C" and "M" on a computer keyboard with the left and right index finger. The assignment of the key to the response category (Targets vs. Nontargets) was balanced across participants. The whole experiment took about 2.5 h (including preparation time for EEG recording).

2.3. Stimuli

Verbal material was presented on a 17 in. monitor in white 22 pt Courier New font on a black background. All displays were at the center of the computer screen, with participants sitting 60–80 cm in front of it. Study items consisted of object names with a word length between 3 and 11 characters and a word frequency ranging from 1 to 409 occurrences per million. Word frequency was checked with the dlexDB linguistic database (http://dlexdb.de; Brysbaert et al., 2011). A total of 184 object names were selected as study items. Object names were grouped into two lists of 92 items. One list was assigned to the vocalize condition (speaking out the word aloud) and the second list to the imagine condition (imagine a picture of the denoted object). The list assignment to the study conditions was counterbalanced across participants. Furthermore, the word length and word frequency of the two lists did not differ between lists and their halves. The order of test conditions was counterbalanced across individuals, but remained the same within the two test blocks of an individual. In each of the test conditions, there were 46 targets to be identified, and 46 old items of the second study condition (in the following labeled as nontargets), together with 46 new items that had to be rejected.

2.4. EEG recordings

EEG was recorded with 58 embedded silver/silverchloride EEG electrodes that were attached to the participant's head in an elastic cap (Easycap, Herrsching, Germany) prior to the study phase. Electrode locations in the used caps are based on an extended 10–20 system (10–10 system). Electrode impedances were kept below 5 kΩ. EEG was continuously recorded, referenced to the left mastoid. In addition, electroocular activity was recorded by a pair of electrodes affixed to the outer canthi and by a pair of electrodes placed below and above the right eye. Data were sampled at 500 Hz and filtered online from 0.016 Hz (time constant 10 s) to 250 Hz.

Offline, data were digitally filtered from 0.1 Hz to 40 Hz (48 dB), with an additional notch filter at 50 Hz to suppress line activity, and re-referenced to linked mastoids. Data were down-sampled to 200 Hz, segmented into epochs of 3000 ms duration, including a 500 ms baseline, and exported to EEGLab (Swartz Center for Computational Neuroscience, University of California San Diego, USA). The influence of eye movements and blinks on EEG activity, as well as of electrocardiographic and other artifacts was corrected by an independent component analysis (ICA). After that, data were screened for artifacts that could not be corrected by the ICA procedure: trials with EEG activity exceeding ±100 μV, exhibiting abnormal trends (R^2 limit = 0.3), or being abnormally distributed (±5 SD from the mean) were excluded. Data were exported to BrainVision Analyzer 2.03 (Brain Products, Gilching, Germany). For each test condition, average ERPs were calculated for hit targets (T), as well as for correct rejections of nontargets (NT) and new items (NEW). Individual ERPs were only considered for analysis if a minimum of 15 trials was accepted. If this criterion was not reached, participants were excluded. For statistical analyses, amplitude values were exported from BrainVision Analyzer into SPSS 21.0 (IBM). ERP and current source density (CSD) maps were created in BrainVision Analyzer as well. CSD are the second spatial derivative of the spline-interpolated potential maps (Perrin et al., 1989). This transformation represents a spatial filter that isolates those aspects of the EEG that can be unambiguously associated with superficial generators in the immediate neighborhood of an electrode (Srinivasan, 2005) and that suppresses widely distributed potentials which result from volume conduction from far field sources (Perrin et al., 1987). Given this, CSD detects primarily (radial) sources in the superficial gyral surfaces of the cortex (Srinivasan, 2005).

2.5. Data analysis

Behavioral data: Behavioral measures were calculated for each test condition, with test conditions designated by the indices IT (imagined item target condition) and VT (vocalized item target condition). Retrieval accuracy was quantified by the hit rate (P_target), rate for correct rejections of new items (P_new), rate for missed responses (P_no response), false alarm rate for nontargets (P_false alarms), and the discrimination index (Pr) which is the difference between the hit rate and the false alarm rate to nontargets (Snodgrass & Corwin, 1988). Reaction times (RTs) were quantified for correct responses only. Behavioral measures were compared between the two test conditions by means of paired *t*-tests and repeated measure analysis of variance (ANOVA).

ERP data: In order to explore the retrieval orientation effect, ERPs to new items were contrasted between the IT and VT conditions. For the time range from 300 ms to 1000 ms, mean amplitudes of these ERPs were quantified for 100-ms time bins each and compared between the two test conditions (IT vs. VT condition) by paired *t*-tests for each of the 58 scalp electrodes. As also in a previous study (Rosburg et al., 2011a), *P* values of $p < 0.05$ but $p > 0.01$ were regarded as significant only if neighboring electrodes or neighboring time windows showed a significant condition effect at $p < 0.01$. This approach provides a better understanding of the overall distribution of the retrieval orientation effect than a conservative correction of the significance level. In order to allow a more concise presentation of the retrieval orientation effects, time windows with significant retrieval orientation effects were collapsed in a second step of analysis. For the sake of brevity, only the latter will be reported here.

In order to analyze the presence of target and nontarget recollection, ERPs to targets, nontargets and correct rejections were compared at a representative electrode (P5) by a repeated-measure ANOVA with STIMULUS (T, NT, NEW) and CONDITION (IT, VT) as within-subject factors. Electrode P5 was selected because the parietal old/new effects had the largest amplitude at it. As in a previous study using imagined items as study material (Rosburg et al., 2011b), a time window between 600 and 900 ms was used for this analysis. In case of significant interactions between STIMULUS and CONDITION, STIMULUS effects were further evaluated by a repeated measure ANOVA with STIMULUS as within-subject factor within each condition and subsequent paired *t*-tests. The Greenhouse–Geisser adjustment for nonsphericity was used when necessary, as indicated by reporting the ε value, and the corrected *p* values are reported together with the uncorrected degrees of freedom. Of note, other old/new effects were analyzed as well, but we considered them as being little informative with regard to current study purpose and refrained, therefore, from reporting them. For example, the early midfrontal old/new effect (300–500 ms) was present for targets and nontargets, but it did not show any variation between the two and did not differ between conditions either. The late right-frontal old/new effect (900–1500 ms) was generally larger for targets than for nontargets, but was not modulated by CONDITION.

Data analyses were first run for the total sample. In order to evaluate the impact of retrieval accuracy, the group was divided into high and low performers by median-split of the mean Pr value (Pr_mean = 0.5 ($Pr_{IT} + Pr_{VT}$). Subsequently, data analyses were run for each subsample. In order to assess the influence of test order, the sample was divided into participants who started with the VT condition and into those who started with IT condition. The subsamples always consisted of 16 participants. The two subdivisions resulted in largely independent subsamples (seven low performers started with the VT condition, nine with the IT condition). For assessing the impact of retrieval accuracy and test order on behavioral measures, measures were directly compared between the subsamples. When evaluating the effect of retrieval accuracy and test order on retrieval orientation and old/new effects, the corresponding grouping factor was used as between-subject factor.

3. Results

3.1. Behavioral

The analysis of the behavioral data of the test phase revealed better retrieval accuracy for imagined items than for spoken items: The hit rate for imagined items was significantly higher than for spoken items ($t_{31} = 7.991$, $p < 0.001$, Table 1), while false alarms to nontargets did not vary between test conditions ($t_{31} = 1.731$, n.s.). Consequently, the discrimination index Pr was larger when imagined items were targeted ($t_{31} = 5.364$, $p < 0.001$). In line with this finding, the correct rejection (CR) rate to new items was higher when imagined items were targeted ($t_{31} = 3.066$, $p = 0.004$). The order of test conditions had an impact on the rate of false alarms for imagined items as nontargets in the VT condition. The rate was significantly higher when imagined items were targeted first than when vocalized items were targeted first (P_false alarm: 0.19 ± 0.10 vs. 0.11 ± 0.06, $t_{30} = 2.692$, $p = 0.011$). All other accuracy measures were not influenced by test order.

For RTs, a repeated-measure ANOVA with ITEM (Target, Nontarget, New items) and CONDITION (VT, IT) as within-subject factors revealed significant main effects and interaction (ITEM: $F_{2,\ 62} = 67.087$, $p < 0.001$, $\varepsilon = 0.783$; CONDITION: $F_{1,\ 31} = 4.499$, $p = 0.042$; ITEM × CONDITION: $F_{2,\ 62} = 13.302$, $p < 0.001$, $\varepsilon = 0.736$). Between conditions, RTs differed for targets ($t_{31} = 4.056$, $p < 0.001$) and on a trend level for new items ($t_{31} = 1.953$, $p = 0.060$), with faster RTs for these items when imagined items were targeted (Table 2). No CONDITION effect was found for the RTs to nontargets ($t_{31} = 0.553$, n.s.). The RTs were faster for new items than for both kinds of old items (Targets, Nontargets) in both conditions (all $t_{31} > 6.450$, $p < 0.001$). Participants responded faster to targets than to nontargets when imagined items were targeted ($t_{31} = 3.754$, $p = 0.001$), while these RTs did not differ when spoken items were targeted ($t_{31} = 0.633$, n.s.). RTs did not vary significantly between sub-samples (high vs. low performers, participants with different test orders) but RTs to correct rejections in the VT condition showed a tendency for being shorter when participants started with this condition than when participants started with the IT condition ($t_{30} = 1.816$, $p < 0.1$).

Table 1
Memory accuracy.

	Vocalized target	Imagined target
All		
P_target	0.64 ± 0.14	0.84 ± 0.11
P_false alarm	0.15 ± 0.09	0.19 ± 0.11
Pr	0.49 ± 0.16	0.65 ± 0.17
P_new	0.95 ± 0.06	0.97 ± 0.06
P_no response	0.007 ± 0.015	0.008 ± 0.019
IT first		
P_target	0.64 ± 0.16	0.83 ± 0.14
P_false alarm	0.19 ± 0.10	0.20 ± 0.11
Pr	0.45 ± 0.19	0.63 ± 0.20
P_new	0.93 ± 0.06	0.97 ± 0.06
P_no response	0.011 ± 0.020	0.011 ± 0.025
VT first		
P_target	0.64 ± 0.12	0.84 ± 0.07
P_false alarm	0.11 ± 0.06	0.18 ± 0.11
Pr	0.53 ± 0.12	0.67 ± 0.16
P_new	0.96 ± 0.05	0.98 ± 0.06
P_no response	0.003 ± 0.005	0.003 ± 0.006

Table 2
Reaction times (RT) (ms).

	Vocalized target	Imagined target
All		
RT_hits	956.1 ± 306.3	804.7 ± 255.8
RT_CR_old	957.6 ± 308.3	978.8 ± 331.2
RT_CR_new	656.5 ± 281.9	597.1 ± 183.7
IT first		
RT_hits	975.6 ± 342.5	800.2 ± 275.3
RT_CR_old	960.3 ± 331.8	1007.5 ± 348.0
RT_CR_new	743.9 ± 360.2	629.6 ± 230.3
VT first		
RT_hits	936.7 ± 275.3	809.0 ± 243.8
RT_CR_old	955.0 ± 293.8	950.1 ± 322.4
RT_CR_new	569.2 ± 135.1	564.5 ± 120.2

3.2. ERPs

3.2.1. Retrieval orientation

An effect of retrieval orientation was detected from 500 to 800 ms for the sample as a whole. The effect was maximal at electrode T7 (Fig. 2A and D), but was rather small in amplitude and did not reach the pre-defined α level of $p < 0.01$ (electrode T7, $t_{31} = 2.197$, $p = 0.036$). The ERPs to new items in the two conditions, as well as the difference potential were subjected to a transformation into CSD maps. The CSD map of the difference potential shows a source over left-temporal regions (C5: $t_{31} = 2.920$, $p = 0.006$; T7: $t_{31} = 2.643$, $p = 0.013$), and a sink over left-frontal regions (F3: $t_{31} = 2.510$, $p = 0.018$; F1: $t_{31} = 2.234$, $p = 0.033$, Fig. 2A bottom). CSD amplitudes of the source as measured at electrodes C5 and T7 did not correlate with the CSD amplitudes of the sink at the two frontal electrodes ($-0.171 < r < -0.116$, n.s.). Thus, it appears unlikely that the source and sink were generated by the same cortical structure.

In order to analyze the impact of test order and retrieval accuracy on the retrieval orientation effect, ERPs to new items in each condition were compared between the two test conditions in each subsample, created by median split (low vs. high retrieval accuracy), or by subdividing the sample in participants with different test orders in the memory exclusion task (first VT vs. first IT condition). Retrieval orientation effects were observed in participants with high retrieval accuracy and in participants who were first tested for vocalized items, but not in the complementary sub-samples. In participants with high retrieval accuracy, the retrieval orientation effect was statistically most reliable at T7 ($t_{15} = 2.983$, $p = 0.009$) (Fig. 2B and D). The retrieval orientation effect in participants who were tested first in the VT condition was most pronounced over parieto–occipital electrode sites (CP1, CP2, CP3, CP4, CP5, P1, P2, P3, P4, P5, Pz, PO3, PO7, O1, O2, Oz; each $t_{15} > 2.994$, $p < 0.01$); the effect was numerically and statistically largest at Pz ($t_{15} = 4.216$ $p < 0.001$) (Fig. 2C and D).

In order to disentangle the effects of test order and retrieval accuracy on retrieval orientation in this latency range, a factor analysis with varimax rotation was run. The amplitude differences between the ERPs to new items in the VT and IT condition at each EEG channel from 500 to 800 ms were entered as depended variables into this analysis. Four factors were extracted. The first two rotated factors explained most of the variance (41.9% and 34.3%). The first factor showed strong loadings at parieto–occipital electrodes, the second factor at fronto-central electrodes. The individual scores of the first factor differed between participants with different test orders ($F_{1,\ 31} = 20.861$, $p < 0.001$), but not between high and low performers ($F_{1,\ 31} = 0.288$, n.s.). Conversely, the individual scores of the second factor varied between low and high performers ($F_{1,\ 31} = 6.322$, $p = 0.018$), but not between participants with different test orders ($F_{1,\ 31} = 0.022$, n.s.). In line with that, the mean retrieval accuracy (Pr_mean) correlated with the factor scores of the second factor ($r = 0.505$, $p = 0.003$), but not with the scores of the first factor ($r = 0.195$, n.s., Fig. S1). When the individual scores of the two factors were simultaneously entered into a

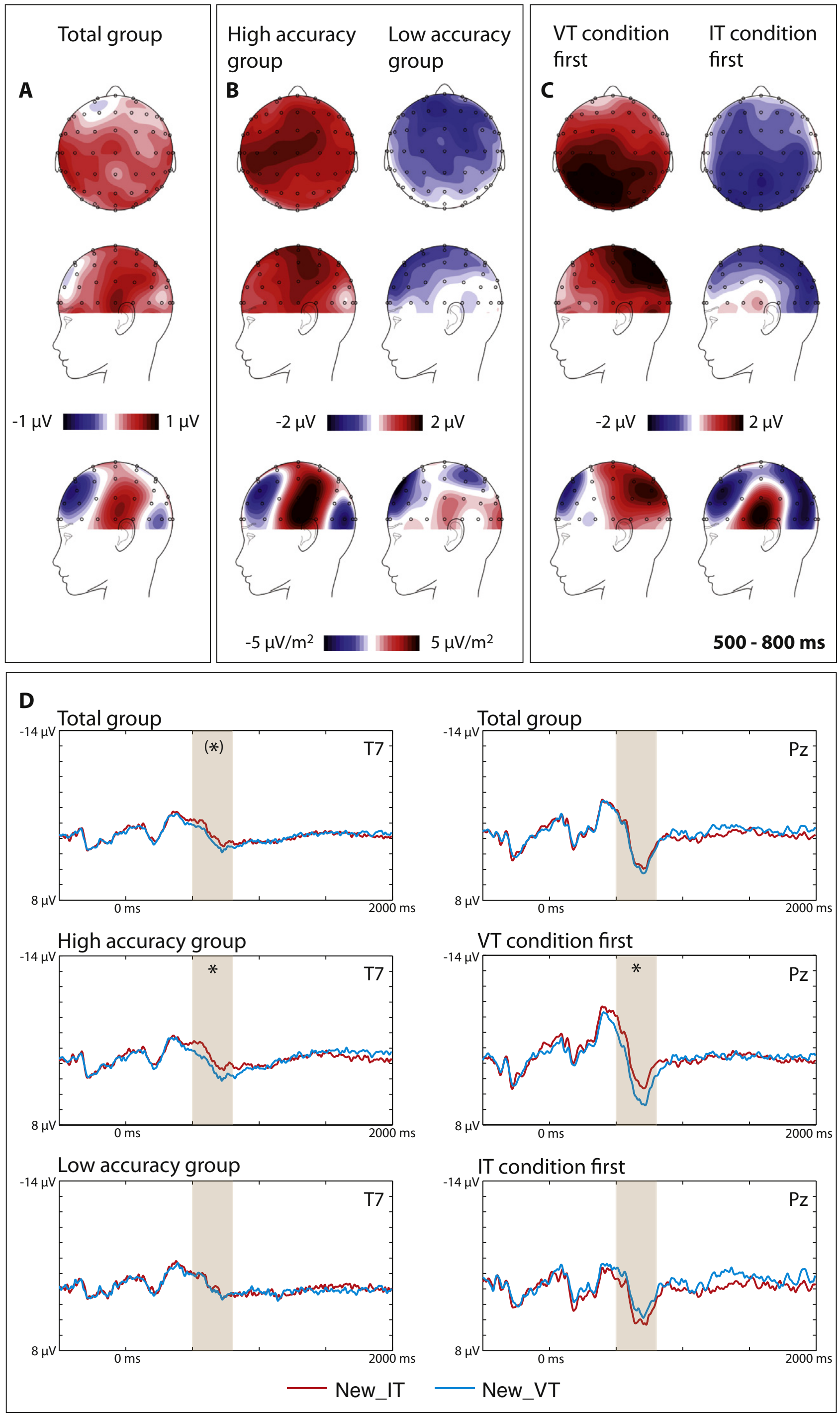

Fig. 2. ERP retrieval orientation effects: The topography of the retrieval orientation effect (ERPs to new items in the VT condition – ERPs to new items in the IT condition) between 500 and 800 ms in the total sample (A), in the subsamples of participants with high and low retrieval accuracy (B), and in the subsamples with different test orders (C); the two top rows show the ERP scalp maps from the top and from the left direction; note the different scaling for the total sample and the subsamples, as indicated by the horizontal color bars below the maps; the bottom row shows the CSD maps from the left; for the CSD maps, scaling is identical for the total sample and the subsamples; (D), the ERPs to new items in the VT condition (blue) and in the IT condition (red) are depicted at electrodes T7 and Pz; at these electrodes, the largest retrieval orientation effects were found for participants with high retrieval accuracy and participants who started their testing with the VT condition; the ERPs for the total group are depicted at the top; the ERPs of the subsamples is showed below. The critical latency range (500–800 ms) is marked by shading; significant differences ($p < 0.01$) are marked by asterisks. The ERPs to new items for the total group at T7 differed with a p value <0.05, but $p > 0.01$.

two-way ANOVA, no significant interactions between test order and retrieval accuracy were observed for the individual scores of the two factors (both $Fs_{1,\ 28} < 1.228$, n.s.). These comparisons show that the retrieval orientation effect between 500 and 800 ms was independently modulated by test order and retrieval accuracy.

3.2.2. Left parietal old/new effect (600–900 ms)

The overall ANOVA revealed a significant effect of STIMULUS ($F_{2,\ 62} = 10.411$, $p < 0.001$, $\varepsilon = 0.801$); and a significant STIMULUS × CONDITION interaction ($F_{2,\ 62} = 5.822$, $p = 0.005$). Subsequent analyses for each condition showed that in the IT condition the left-parietal old/new effect was present for targets, but not for nontargets ($F_{2,\ 62}$ = 14.638, $p < 0.001$, $\varepsilon = 0.733$, Fig. 3A and C). In this condition, the ERPs to targets were also more positive than ERPs to nontargets (t_{31} = 5.531, $p < 0.001$). In contrast, in the VT condition the parietal old/new effects were only weakly pronounced and reached significance only for targets ($F_{2,\ 62}$ = 3.914, $p = 0.025$), but with no apparent difference between the ERPs to targets and nontargets (t_{31} = 0.954, n.s., Fig. 3A and C).

Retrieval accuracy did not modulate the left parietal old/new effect for any kind of item (targets, nontargets) and any condition

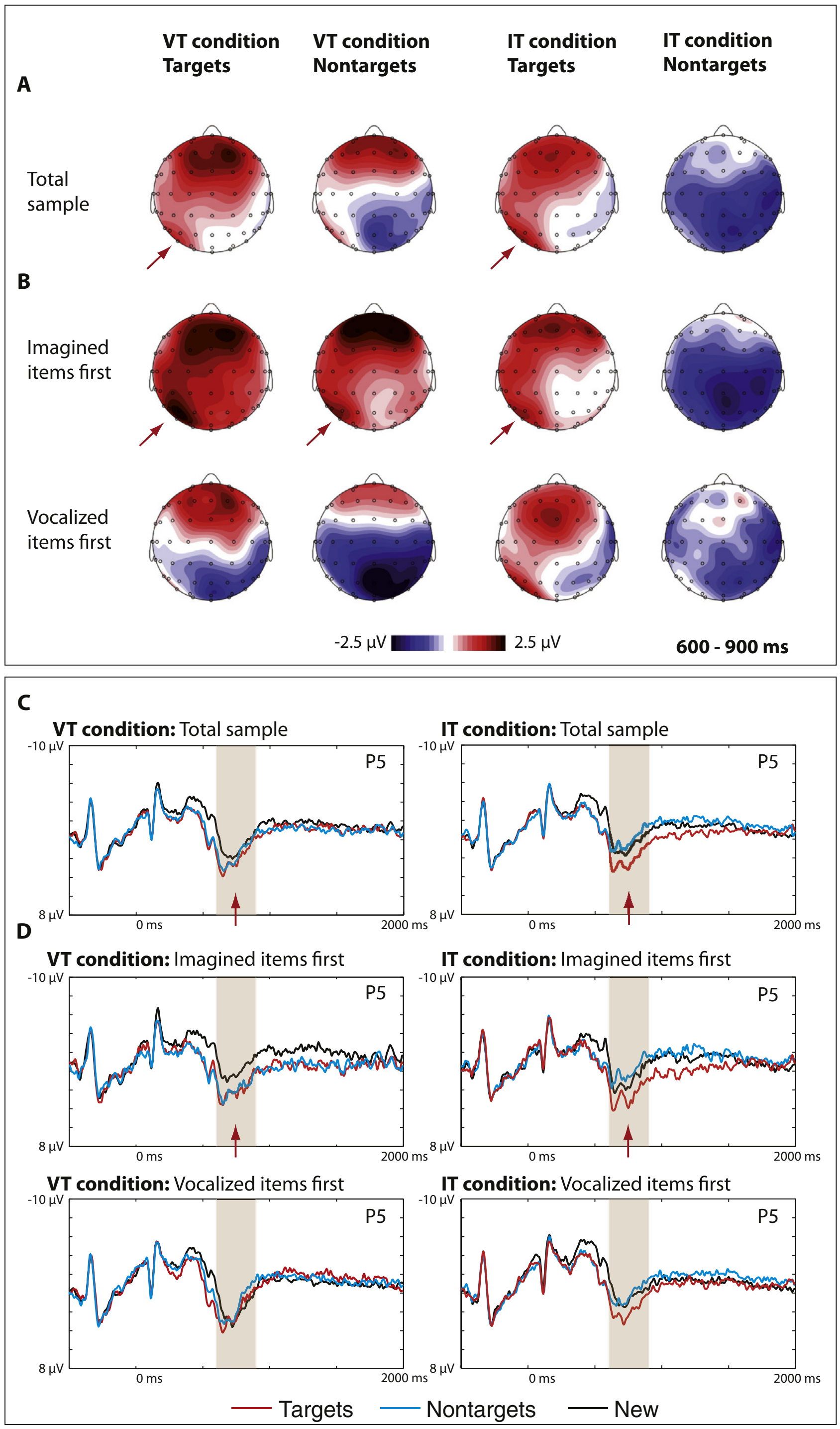

Fig. 3. Old/new effects from 600 to 900 ms: (A) the topography of the old/new effects for the total sample, for targets and nontargets in each of the two target conditions, as well as for the two subsamples with different test orders: In the total sample, only targets elicited a parietal old/new effect (indicated by the red arrow). In the IT condition, the effect was statistically much more reliable than in the VT condition. (B) In the VT condition, the left-parietal old/new effects varied between participants with different test orders. When participants started with the IT condition, the left parietal old/new effects were present for targets and nontargets, but the effects were completely absent when they started with the VT condition (left side). In the IT condition, test order did not significantly modulate old/new effects (right side). (C) The ERPs to hit targets (red lines), as well as correct rejections of nontargets (blue lines) and new items (black lines) at the left-parietal electrode P5, for the two target conditions separately. (D) The same ERPs for the two subsamples with different test orders: Significant left-parietal old/new effects between 600 and 900 ms are again indicated by red arrows. Note that a left-parietal old/new effect to nontargets in the VT condition was revealed only for participants who started with the IT condition.

(VT, IT) (all $Fs < 0.622$, n.s.). In contrast, test order modulated the effect in the VT condition for targets ($F_{1,\ 30} = 4.930$, $p = 0.034$) and nontargets ($F_{1,\ 30} = 7.895$, $p = 0.009$), but for neither of them in the IT condition (both $Fs_{1,\ 30} < 1.406$, n.s.), as shown by one-way ANOVAs. In the VT condition, the left-parietal old/new effects were present for targets and nontargets when participants started with the IT condition ($F_{2,\ 30} = 8.820$, $p < 0.001$), with no difference between ERPs to targets and nontargets ($t_{15} = 0.279$, n.s.). The effects were, however, absent when participants started with the VT condition ($F_{2,\ 30} = 0.517$, n.s., Fig. 3B and D).

4. Discussion

The main findings of our study can be summarized as follows: (1) we revealed a retrieval orientation effect (500–800 ms) that was characterized by a more positive ERP response to new items in the VT than in the IT condition at the left-temporal electrode T7. Transformation of this effect into a CSD map indicated a left-temporal source in the vicinity of the auditory cortex. (2) The early retrieval orientation effect was independently modulated by retrieval accuracy and test order. The described left-temporal effect was primarily found in participants with high retrieval accuracy. Furthermore, targeting first vocalized items resulted in an early retrieval orientation effect that was characterized by more positive ERPs to new items over left parieto–occipital regions in the VT than in the IT condition. (3) In the easier IT condition, the left-parietal old/new effect (600–900 ms) was only present in response to targets. In the more difficult VT condition, the left parietal old/new effect was modulated by test order. Whereas the effect was present for both targets and nontargets in participants who started with the IT condition, it was completely absent in participants who started with the VT condition. In the following, we will address these findings in detail.

4.1. Retrieval orientation effect

As outlined in the introduction, a prerequisite for the observation of retrieval orientation effects is that the retrieval of target information is prioritized over the retrieval of nontarget information in at least one condition (Dzulkifli et al., 2006). Such selective retrieval was indeed observed in the current study: In the IT condition, the left-parietal old/new effect (600–900 ms) was present in response to targets, but absent to nontargets. Based on this pattern, we presume that participants did not attempt to retrieve auditory (nontarget) information in this condition. In contrast, participants presumably attempted to retrieve auditory *and* visual information in the VT condition, as indicated by the presence of left-parietal old/new effect to targets and nontargets in this condition.

For investigating the retrieval orientation effect, we contrasted the ERP responses to new items when vocalized items were targeted to ERP responses to new items when imagined items were targeted. The comparison of these two ERP responses showed that ERPs were more positive going over left temporal regions from 500 to 800 ms when vocalized items were targeted. Additionally, CSD maps were calculated since such maps are more informative about underlying cortical generators than conventional scalp maps. CSD mapping of the retrieval orientation effect showed a left-temporal source and left-frontal sink. It appears likely that the sink and the source reflect activity of two distinct generators, as their amplitudes were not correlated across participants.

The observation of a left-temporal source supports the notion that retrieval orientation toward vocalized information is associated with an activation of the auditory cortex. The finding also provides evidence that retrieval orientation processes directly operate on the level of memory representations ('target bias', Dzulkifli & Wilding, 2005) and that episodic memory retrieval involves processes or representations that were active when these episodes were encoded ('reinstatement hypothesis', Rugg et al., 2008). So far, such an involvement of modality-specific cortical regions in retrieval orientation has been shown only by a single fMRI study (Hornberger et al., 2006a). In contrast to this fMRI study, we did not observe a complementary response pattern when visually encoded items of the imagine condition were targeted. Over occipital (visual) regions the ERPs to new items did not vary systematically between the two test conditions. Thus, it appears that visual regions were not engaged to greater extent in retrieval attempts for imagined items than for vocalized items. One tentative explanation for this finding is that visual regions might have been engaged to a similar extent in retrieval attempts of both conditions because participants attempted to retrieve visual information not just in the IT condition, but also in the VT condition, as indicated by the presence of a left-parietal old/new effect to nontargets in this condition. Moreover, it might also be argued that that visual areas were activated to a similar extent in retrieval attempts of the two test conditions because visual word cues were used in both study conditions.

Consistent with our prediction that retrieval accuracy is modulated by retrieval orientation, large and highly significant left-temporal retrieval orientation effects were found in participants with high retrieval accuracy, whereas this effect was insignificant in participants with low retrieval accuracy. This finding is well in line with previous ERP studies that revealed retrieval orientation effects in participants with high retrieval accuracy, but no such effects in participants with low retrieval accuracy (Bridger & Mecklinger, 2012; Bridger et al., 2009; Sprondel et al., 2013). Together with these previous findings, the current finding supports the view that adopting retrieval orientation is potentially beneficial for retrieval accuracy, as initially suggested by Bridger et al. (2009). However, a positive association between retrieval accuracy and the magnitude of the retrieval orientation effect is not found in all retrieval orientation studies: some studies reported that within subjects the retrieval orientation effect did not vary with retrieval accuracy (Morcom & Rugg, 2004; Robb & Rugg, 2002). In other studies, the retrieval orientation effect increased across subjects with increasing (and not with deceasing) retrieval difficulty (Dzulkifli, Sharpe, & Wilding, 2004; Rosburg et al., 2011a), suggesting that sometimes retrieval orientation might be adopted to a greater extent when participants experience greater difficulties at retrieval. In light of these divergent findings, we have previously argued that a positive correlation between retrieval accuracy and retrieval orientation might be found in particular when the two kinds of target information are dissimilar and, in consequence, selective activation and inhibition of target representations are possible (Rosburg et al., 2011a). The current findings are highly consistent with this view, as only items of the vocalize condition were associated with auditory information.

However, we acknowledge that the similarity of target and nontarget information was not systematically varied in our study. Moreover, the distinctiveness of the target information might be of particular relevance when retrieval orientation is studied by ERPs which have a relatively poor spatial resolution. By using fMRI with its much superior spatial resolution, it might be possible to identify cortical regions that show a negative association and other regions that show a positive association between retrieval accuracy and retrieval orientation, even when the targeted information is relatively *similar*. To our knowledge, the impact of retrieval accuracy on retrieval orientation has so far not been studied by fMRI. Some prior fMRI studies investigated retrieval orientation by contrasting inclusion and exclusions tasks (i.e. two memory tasks that fundamentally differ in task difficulty), but these studies revealed heterogeneous results (Ranganath, Johnson, & D'Esposito, 2000; Rugg, Henson, & Robb, 2003).

4.2. Effects of test order

The retrieval orientation effect was modulated not just by retrieval accuracy, but also by test order. ERPs to new items in the VT condition were more positive over parieto–occipital regions than ERPs to new items in the IT condition when participants first targeted vocalized items, whereas no such effect was observed when they first targeted imagined items. The finding was not expected. To our knowledge there are no previous reports of test order effects on retrieval orientation. It is important to note that the effects of test order and retrieval accuracy on the ERP retrieval orientation effect did not interact and that test order had no impact on retrieval accuracy but on the false alarm rate. Thus, the effect of test order does apparently not represent a secondary effect of retrieval accuracy. Notably, test order also modulated the left-parietal old/new effect: The left-parietal old/new effects to targets and nontargets were absent in the VT condition when participants started with it. Presumably, the increased positivity of ERPs to new items at posterior recordings led to an abolishment of the left-parietal old/new effect for these participants in this condition. Pairwise comparisons of the ERPs at electrode P5 between 600 and 900 ms revealed a significant condition effect for new items (t_{15} = 3.856, p = 0.002), but not for target items (t_{15} = 0.339, n.s.) in these participants. With other words, in this subgroup the parietal retrieval orientation effect was present for new items but not for old items. As lined out in the introduction, retrieval orientation is usually studied by contrasting the ERP responses to new items, but nevertheless one would expect that genuine retrieval orientation effects were also present to some extent in the ERP response to old items.

In light of this finding, we think that the test order effect on ERPs to new items reflects a differential processing of newness in the two test conditions as a function of test order. The task difficulty in the VT condition was considerably larger than in the IT condition. When participants started with the more difficult condition, they might have had some tendency for first identifying new items (which was apparently easier) and then dealing with "unnew" items. This performance strategy might have enhanced the task relevance of unstudied items and might have given rise to a P300, an ERP component which is highly associated with the task-relevance of an item (Polich, 2007). In line with the assumption of a differential processing of newness, the RTs to correct rejections in the VT condition showed a tendency for being shorter when participants started with this condition than when participants started with the IT condition. Future studies are warranted in order to elucidate whether and under which conditions participants prioritize the information of newness of test items over the information of their oldness. The finding suggests that the absence of old/new effects can sometimes be the consequence of how new items (rather than the old items) are processed.

4.3. Nontarget retrieval

Previous studies have shown that task difficulty has an influence on whether nontarget information is retrieved in memory exclusion tasks or not (Herron & Rugg, 2003; Wilding, Fraser, & Herron, 2005). The basic assumption is that retrieval of nontarget source information allows swift rejection decision for nontargets when target retrieval is difficult ('recall-to-reject', Clark, 1992). However, when target retrieval is easy subjects might instead prioritize the target information (and neglect nontarget information). In this case, items are endorsed as targets when their recognition is accompanied by the retrieval of matching source information and items are rejected as nontargets when no such matching information can be retrieved (Herron & Rugg, 2003). Thus, nontargets are rejected without retrieving their actual source.

The current findings on the left-parietal old/new effect to targets and nontargets are well in line with the account of Herron and Rugg (2003): In the easier IT condition, the left-parietal old/new effect was present to targets, whereas it was absent for nontargets (Fig. 3A and C), suggesting that target information was prioritized. In the more difficult VT condition, the left-parietal old/new effect was modulated by test order. When participants started with the VT condition, the left-parietal old/new effects were completely abolished presumably due to a P300 to new items. For evaluating the aspect of nontarget retrieval, we will therefore primarily consider the data of participants who started with the IT condition. Those participants showed a left-parietal old/new effect to targets and to nontargets, with little variation between the two of them (Fig. 3B and D, as indicated by the red arrows). The findings suggest that in the more difficult condition these participants indeed relied on both target and nontarget information, as predicted by the account of Herron and Rugg (2003). However, in contrast to a previous own study (Rosburg et al., 2011b), we found no evidence that the retrieval accuracy in the more difficult condition was modulated by the magnitude of the left-parietal old/new effect to nontargets: the left-parietal old/new effects to nontargets (and targets) did not vary between participants with high and low retrieval accuracy.

5. Conclusion

Contrasting the ERPs to new items revealed two different effects: the left-temporal retrieval orientation effect is presumed to reflect the contribution of auditory regions to cue specific processing. By this, the data are consistent with the reinstatement theory of remembering according to which retrieval involves the reactivation of sensory cortices that were active during initial encoding (Rugg et al., 2008). This left-temporal retrieval orientation effect was primarily found in participants with high retrieval accuracy. This indicates that effective cue processing is potentially beneficial for retrieving the task-relevant information, as also suggested by the studies of Bridger et al. (2009), Bridger and Mecklinger (2012). The second, posterior effect was only observed in participants who started with the more difficult test condition. This effect did not show a modality specific scalp distribution and might be associated with a performance strategy, namely focusing on the newness of items. This might have enhanced the task-relevance of new items and led to a P300-like response to new items.

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Appendix A. Supplementary material

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.bandc.2014.10.011.

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