Feigning memory impairment in a forced-choice task: Evidence from event-related potentials

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Abstract

Strategies of malingering detection have brought about a wealth of neuropsychological studies in the last decades. However, the investigation of physiological measures to reliably differentiate between authentic and manipulated symptom presentations is still in its infancy. The present study examined event-related potentials (ERP) to identify feigned memory impairment. We tested instructed malingerers ($n = 25$) and control participants ($n = 22$) with a recognition task similar to the Test of Memory Malingering. No differences between groups were found for P1 (70-110 ms) but for N1 (120-170 ms) and P300 components, with lower amplitudes for instructed malingerers. Behavioral data showed a typical pattern of unrealistically high errors in a forced-choice recognition task and less overall recalled stimuli in instructed malingerers. We also found study-phase repetition and old/new effects in the P300, but no interactions with groups (control vs. malingering). Post-hoc analyses revealed that the P300 effect is greater when participants reported an attention-based faking strategy, as opposed to response-based malingerers and controls. The employment of physiological measures can yield additional information on the validity of test data without the need to perform additional tests.

Keywords: Malingering, Event-related potential, classic old/new effects, Performance validity testing, Attention, Recognition

1. Introduction

1.1. Symptom and performance validity assessment

In the legal arena, neuropsychologists are regularly consulted for expert opinions about the presence, nature, extent, and authenticity of cognitive impairment. Claims of cognitive impairment often occur in situations in which either highly positive or negative consequences for an individual are at stake, such as financial compensation after an accident or the lack of those. In forensic neuropsychological evaluations, symptom and performance validity assessment is essential to differentiate between true cognitive impairment and exaggerated or invented claims of dysfunction (e.g. Bush et al., 2005; Heilbrunner, Sweet, Morgan, Larrabee, Millis, & Conference Participants, 2009).

While there are many ways a person can feign malfunctioning, one of the most prominent domains of malingered symptoms is cognitive impairment (Larrabee, 2003; Mittenberg, Patton, Canyock, & Condit, 2002). This is explained by the simplicity of feigning cognitive impairment. First, while it is possible to validate cognitive impairment in physically identifiable brain injuries, it is not possible to exclude cognitive impairment in the absence of physical injuries. Second, there seems to be a multitude of situations that can elicit possible cognitive impairment. Third, people do not need to learn how to feign cognitive impairment credibly, although it is well known that layperson's knowledge about cognitive impairment is not always accurate (Aubrey, Dobbs, & Rule, 1989; Slick, Sherman, & Iverson, 1999). In general, people have sufficient knowledge about symptoms of cognitive impairment, which enables them to successfully fake it (Lees-Haley & Dunn, 1994; Mittenberg, DiGiulio, Perrin, & Bass, 1992). Slick et al. (1999) developed diagnostic criteria for malingered neurocognitive disorders (MND). At the outset, a necessary condition for classifying feigned symptom presentation is the presence of a substantial external incentive (criterion A). The second criterion (B) is evidence from neuropsychological testing. Definite evidence would be

a performance below chance in a forced-choice test. Less definite but important evidence is obtained from an analysis of plausibility (e.g., the discrepancy between test data and known patterns of brain functioning or observed behavior). Recently, an update of these criteria has been published by Sherman, Slick, and Iverson (in press).

Performance validity tests (PVTs), formerly known as cognitive symptom validity tests, were developed to determine whether the test performance of a person in question can be judged to be valid or, the results of suboptimal test motivation. Most freestanding PVTs appear to be more difficult than they are in truth. They seem to measure, for instance, memory but, in fact, they measure test motivation. They have good face validity when a test person judged the test to be more difficult than it truly is. Therefore, a patient who invents or exaggerates cognitive dysfunction is induced to overdo its symptom claim. In a case like this, the PVT result would correctly classify invalidity of test profile but not authentic cognitive impairment. The classic principle of test construction of these PVTs is the forced-choice format. Some examples of such PVTs are the Word Memory Test (WMT; Green, 2003), the Test of Memory Malinger (TOMM; Tombaugh, 1996), and the Medical Symptom Validity Test (MSVT; Green, 2004).

While symptom validation assessment is highly accurate (Brockhaus & Merten, 2004; Merten, 2013; Stevens & Merten, 2010), the results of a single test are not sufficient to validate cognitive impairment (Slick et al., 1999). Yet, symptom or performance validity assessment is not limited to the employment of freestanding tests, but should include all available information on a case and submit it to a comprehensive analysis of plausibility and consistency (e.g., Larrabee, 2005; Slick et al., 1999). This would result in a multimethod approach to assess the validity of diagnostic information (Giger, Merten, Merckelbach, & Oswald, 2010). There already is some evidence about implicit measures that can be used in a multimethod approach (e.g. Bernard, 1991; Jansen & Schulze, 2020; Reicker, 2008; Vagnini,

Berry, Clark, & Jiang, 2008). However, evidence from physiological measures are underrepresented in research and forensic practice, with only a few exceptions (e.g., van Hooff, Sargeant, Foster, & Schmand, 2009; Shelley-Tremblay, Eyer, & Hill, 2019; Vilar-López, Pérez-García, Sánchez-Barrera, Rodríguez-Fernández, & Gómez-Río, 2011).

The current study resorts to event-related potentials (ERPs) as an additional data source for the detection of feigned memory impairment. ERP components are physiological correlates that allow to capture attention-based processes in the absence of an overt response. Therefore, the main advantage of this kind of data is its implicit nature of the acquisition. While explicit self-reports can be intentionally manipulated, it is questionable whether this is also the case for ERPs. This, in turn, should make it harder to feign impairment without being detected. Additionally, we examine the possibility to identify different malingering strategies, especially to distinguish the strategy of being inattentive from other strategies.

1.2. Memory, Attention, and ERP

The earliest ERP components associated with sensory-evoked attention are the P1 and the N1 components. The P1 component has been proposed to reflect mainly exogenous processes that are not modulated by cognitive processes (Coles & Rugg, 1995). For sensory-evoked visual attention in occipital electrode sites, latencies were typically described to appear at about 90-130 ms (P1) and 160-190 ms (N1) (Mangun & Hillyard, 1990). A positive relationship between these components and performance in attention-demanding tasks was reported (e.g. Kanwisher & Wojciulik, 2000). Mangun and Hillyard (1988, 1990) showed higher amplitudes for P1 and N1 for attentively in contrast to inattentively examined stimuli. Therefore, attention modulates early visual processing (Mangun & Hillyard, 1991). These studies examined task-relevant and task-irrelevant stimuli as well as the spatial focus of

attention (Mangun & Hillyard, 1988). The potential difference between high vs. low attention to the task was not examined.

In contrast, Boksem, Meijman, and Lorist (2005) assumed that with an ongoing task people get mentally fatigued, which in turn should result in less attention to the task. The authors showed that the N1 amplitude decreased with time of participation in the experiment lasting for three hours. Considering this, it seems plausible to assume that less attention to task results in reduced N1 amplitude. In contrast, the P1 did not change with the time on task. Boksem et al. (2005) suggested that the P1 represents exogenous facilitation of early sensory processing, while the N1 rather represents additional top-down modulation of early sensory processing (Boksem et al., 2005, Mangun & Hillyard, 1995). This implies that a generally reduced attention to the task should result in lower overall visual attention at stimulus onset. Therefore, lower N1 amplitude should be apparent in inattentive people.

Another well-studied ERP component sensitive to attention is the P300. A typical time window between 250 and 500 ms was reported, but there is a large variability depending on the task, and the participants investigated (Polich, 2007). The P300 effect probably most well-known is observed in the *oddball* paradigm (Donchin, Ritter, & McCallum, 1978; Polich, 2007). In an oddball paradigm, participants are instructed to respond to an infrequently presented target, but not to a frequently presented standard stimulus (Donchin et al., 1978; Pritchard, 1981). Broad evidence showed that such infrequent target stimuli and the reaction to it produce a relatively unique and strong ERP component, which is a *classic* P300. The explanation for P300 effects is the idea of context-updating (e.g. Polich, 1989; Rushby, Barry, & Doherty, 2005). Attention-driven processes influence the activity reflecting the comparison of the standard stimulus to the new stimulus in working memory. If the stimulus does not change, the schema of the stimulus is unchanged, resulting in a lower P300. If a rare

target is presented, the representation of the stimulus in working memory is updated, which results in an increased positivity (Donchin, 1981; Polich, 1989, 2007).

The relationship of the P300 to memory and attention has also been broadly examined in recognition memory tasks. In a typical study-test task, participants are instructed to learn stimuli during a study phase. In the test phase, they have to discriminate old items against (unstudied) new items. A common finding is a more positive ERP amplitude with old stimuli in a time frame of about 300-700 ms post-stimulus than new stimuli (see e.g. Finnigan, Humphreys, Dennis, & Geffen, 2002; Hutzler, et al., 2007). This effect was often referred to as a P300 old/new effect, which is often most pronounced in centro-parietal scalp electrodes (Rugg & Curran, 2007; Rugg & Nagy, 1989). Several studies also showed that words eliciting higher P300 amplitudes during the study phase were successfully recognized in the later test phase (Karis, Fabiani, & Donchin, 1984, Paller, Zola-Morgan, Squire, & Hillyard, 1988; Rushby, Barry, & Johnstone, 2002). These encoding effects were especially pronounced when the font size of the word was changed, which drew attention and thus resulted in further elaboration of that stimulus. Here also, a larger P300 amplitude at study was reported (Karis et al., 1984). Note that compared to oddball and old/new effects, participants were not necessarily instructed to learn the stimuli; thus, learning occurred incidentally. These reports indicate that altered attention to stimuli at study affects the resulting P300 amplitude (see also Donchin, 1981; Fabiani, Karis, & Donchin, 1986; Noldy, Stelmack, & Campbell, 1990; Polich, 2007). The P300 component reflects the contribution to both, attentional and memory processes (Polich, 2003, 2007, 2012), but it can primarily be seen as a component of promoted memory operations (Polich, 2007).

The P300 is also sensitive to stimulus repetition and repetition priming (see e.g. Rugg & Doyle, 1994). The repetition effect refers to facilitated processing of stimuli on a repeated

presentation, as compared to the initial presentation. The main effect of such repetition is a more positive ERP amplitude at the second presentation (Rugg & Doyle, 1994).

In sum, we propose that the old/new effect can be considered as a special case of a repetition effect. The first presentation elicits a less positive P300 amplitude than the second (and further presentation). Incidental learning especially produces relatively early P300 effects (Noldy, et al., 1990; Fabiani et al., 1986). All effects were apparent in centro-parietal regions and similar early (250-350 ms) or late (400-600 ms) time frames were reported (e.g. Fabiani et al., 1986; Kim, Kim, & Kwon, 2001; Noldy, et al., 1990; Segalowitz, Van Roon, & Dywan, 1997). Due to the similarities between tasks, we expected a similar effect if repeated stimuli are presented during different study phases. For differentiation purposes, we call this the study phase repetition effect.

1.3. Expected ERP effects for Memory Malingering in the Present Study

The idea to combine behavioral data with ERPs for detection of memory malingering is not new (Ellwanger, Rosenfeld, Sweet, & Bhatt, 1996; Ellwanger, Tenhula, Rosenfeld, & Sweet, 1999; Rosenfeld, Sweet, Chuang, Ellwanger, & Song, 1996; Vagnini et al., 2008). For example, Vagnini et al. (2008) used the TOMM and an old/new study-test task to analyze differences in P300 amplitudes. They found old-new P300 effects in honest participants and patients, but not in instructed malingerers, indicating a possible marker for malingering. We extend the idea of Vagnini et al. (2008) to the degree that we include earlier ERP components (P1/N1) to examine if attention-based differences are apparent in people with low test motivation. If so, this should also explain differences in P300 effects.

When asked about the strategy of malingering, participants reported being inattentive or giving false answers in a recognition task as main strategies. A lower degree of attention

could be a strategy to avoid learning the stimuli in the first place. This should result in the need to guess and, in turn, fewer stimuli should be recognized and/or recalled.

First, we expected less negative occipital N1 amplitudes from instructed malingerers as a result of lower visual attention to the task, especially in participants that report attention-based malingering strategies. Considering the P1, we did not expect differences in P1 amplitudes (Boksem et al., 2005). Second, we aimed to replicate Vagnini et al.'s (2008) old/new effect in control participants but not in malingerers. Third, we examined study-phase repetition effects. The P300 amplitudes of stimuli presented a second or third time should be higher than for stimuli that were presented for the first time. Fourth and similar to the absence of the old/new effect in instructed malingerers, we expected a reduced amplitude of P300 in malingerers compared to controls. The reduced P300 mean amplitudes are hypothesized to be a result of less attention to task, and because attentional resources are allocated to strategic malingering. Therefore, no or a lower change between first and subsequent stimulus presentations may be observed. As such, we did not hypothesize that reduced P300 amplitudes should be seen only in participants that report attention-based strategies. However, we speculated that attention-based strategies may further reduce P300 amplitudes, resulting in an interaction of malingering and study-phase repetition effects. The reduced P300 amplitudes and a reduction or absence of the study phase repetition effect in attention-based malingerers is hypothesized to be a result of overall decreased attention. The lower P300 amplitudes on a second and third presentation should be a result of (1) reduced attention to the task in the moment that stimulus is presented and (2) reduced memory of the stimulus due to reduced attention on the past presentations. Finally, the behavioral data should show that instructed malingerers recognized and recalled fewer stimuli and made more errors in a forced-choice task than participants that did not feign such impairment.

2. Method

2.1. Participants

Participants were recruited at the Free University Berlin and the University of Wuppertal via an e-mail distribution list and lectures, therefore most participants were students. Some of the original 59 participants were excluded from analyses due to extremely noisy ERPs ($n = 3$), less than ten trials per condition after excluding trials with artifacts ($n = 2$), and participants working against the instruction or skipping stimuli ($n = 7$). In sum, a total of $N = 47$ participants with a mean age of 24.60 years ($SD = 4.45$) provided data for the analyses. All had normal or corrected to normal vision, and no participant reported a history of neurological illness. The number of cases, the proportion of male and female participants, as well as means and standard deviations of age for each condition, are provided in Table 1. Instructed Malingerers were not older than the ones in the control condition $t(37.062) = -0.55, p = .587$ and did not differ from the expected ratio of the sex $\chi^2(1) = 0.09, p = .763$.

Table 1

Demographic data by condition

Conditions	male		female		age	
	<i>n</i>	%	<i>n</i>	%	<i>M</i>	<i>SD</i>
Control	7	32	15	68	24.22	2.88
Instructed Malinger	9	38	16	62	21.92	5.52

2.2. Stimuli and Procedure

A set of 186 visual stimuli was created for this experiment. All stimuli showed black and white line drawings of very simple objects from ten different categories consisting of vehicles, general objects, clothes, tools, animals, music instruments, nutriments, plants, sports, and technology. The objects were easy enough to be memorized without effort, especially since only the object and no specific details had to be remembered. Therefore, the

stimuli were sufficient to be used in a way similar to the TOMM. The TOMM consists of two learning trials (or study phases) where participants are presented with 50 line-drawings of common objects. The learning trials are each followed by a binary forced-choice recognition task. Our experiment was programmed and run with the software E-Prime (Version 2.0.10.353; Psychology Software Tools, 2013).

The procedure of our study was as follows: participants first filled out informed consent and a short questionnaire with demographic information. Then the EEG cap was put on the participant. Participants were instructed for the procedure of the experiment. They were randomly assigned to either a control or an instructed malingering condition. The control group was asked to follow the procedure as closely as possible. Participants in the instructed malingering condition were instructed to imagine a situation in which they had a car accident two years ago, because of which they had severe impairment in the domain of memory. They should imagine being in a legal situation with the accident causers insurance. At the time of the trial, the deficits in memory were not present anymore. In the following neuropsychological assessment, they should feign cognitive impairment to get compensation for the deficits they had. Then the computerized experiment started, which was similar to the TOMM. For an overview, see Figure 1. Within a first study phase, participants were presented with a random set of 50 line-drawings out of our 186-item set. These 50 line-drawings were set as targets. Participants were instructed to study the visual objects. Within our second study phase, which is not part of the original TOMM procedure, we presented a random subset of 25 targets from the first study phase and an additional random 25 line-drawings which were not shown before. As such, half of the presented stimuli were old (second presentation), the other half was new (first and only presentation). In the third study phase, all 50 targets were repeated, however, the sequence of the presentation was changed. As such, all stimuli were presented before however, half of them were not repeated yet, half

of them were already repeated once. In total, 25 stimuli were shown twice (study phases one and three), 25 stimuli were shown three times (study phases one, two, and three), and 25 items were shown only once (study phase two) within the three study phases.

First study phase (presentation of target stimuli)		
1	2	3 ... 50
Second study phase (presentation of half of the target stimuli, half new stimuli)		
1	2	3 ... 50
Third study phase (presentation of target stimuli in new order)		
1	2	3 ... 50
Fourth block: Binary recognition task (50 target-distractor/ 25 distractor-distractor pairs)		
1	2	3 ... 75
Subsequent recall (all participants), questionnaire (instructed malingers only)		

Figure 1: Examples of line drawings and illustration of the experimental phases.

The fourth phase was a binary forced-choice recognition task. Participants were presented with 75 line-drawing pairs, within 50 of these pairs, one line-drawing was a studied target stimulus, the other one was always a new random line-drawing. In 25 of these pairs, both line-drawings were new. Participants were instructed to recognize the target within the pairs and press the corresponding button. Note that in the 25 pairs with all new line-drawings participants had to guess and ultimately give a false answer. Participants, therefore, were able

to give correct and false answers, but the guessing pairs were not considered as errors but as a response category “guess”.

Within each of the three study phases, we included a picture of the number “8” five times, with the instruction to hit the space bar as fast as possible, if an “8” appears. So, the participants were not able to avoid stimulus presentation by closing the eyes or turning away. These attention checks were not used to exclude participants if they showed delayed or no reaction. The inclusion of our second study phase enabled us to analyze the classic old/new effect and for a more general analysis of the study phase repetition effect.

After the computerized experiment, instructed malingerers were asked to fill out another questionnaire, which functioned as a manipulation check. Questions were, for example, “Did you try to fake cognitive impairment within this experiment?”. Hereafter instructed malingerers were explicitly instructed to stop feigning cognitive impairment. To address recall, all participants had to name all target line-drawings that they truly remember. Instructed malingerers also were asked about their strategy of malingering.

2.3. Data recording

For the data acquisition in Berlin, EEG activity was recorded from 32 Ag/AgCl passive electrodes from 29 participants (11 in the control group). In Wuppertal, a 64-electrodes Brain Products actiCAP system was used for 18 participants (11 in the control group). All electrodes were referenced to A2 (right mastoid). Additionally, two electrodes were placed at the outer canthus and below each eye for horizontal and vertical EOG measurements. The following electrode positions from the international 10-20 system (Jasper, 1958) available for all participants were analyzed: F3, F4, F7, F8, Fz, FC5, FC6, C3, C4, Cz, T7, T8, CP5, CP6, P3, P4, P7, P8, Pz, O1, O2. 32 and 64 channel BrainAmp (Brain Products) amplifiers amplified EEG data. Data was recorded with the BrainRecorder (Brain Products), with a sampling rate of 500 Hz. Impedances were kept below 10 k Ω .

2.4. ERP component analysis

A 0.1-20 Hz, 24 dB/oct, bandpass filter was applied, followed by an EOG artifact correction procedure. EEG data were then divided into segments of 1200 ms length, starting 200 ms before stimulus onset. Trials with potential differences of more than 90 μ V within 50 ms were rejected. Segments were baseline corrected with 200 ms pre-stimulus data as a baseline.

To select particular time frames for analyses, the root mean squared (RMS) time courses were investigated across all electrodes. RMS values and corresponding grand averages for electrodes in focus suggested P1 effects within a time frame of 70-110 ms, N1 effects within a time frame of 120-160 ms, and P3 effects within a time frame of 220-500ms. These time frames are similar to early P300 amplitudes reported within the literature, however somewhat early in comparison to Vagnini et al. (2008). We also analyzed other time frames, without effects. For each person, these time frames were averaged and extracted for analysis. For P1 and N1 effects, occipital electrode clusters were chosen (O1 and O2). Also, frontal electrodes (F3, F4, and Fz) were considered for descriptive activity over scalp areas, but these are not essential for our statistical analyses. For the P300, a parietal electrode cluster was chosen (P3, P4, and Pz) as the highest P300 amplitudes are to be expected in this area of the scalp (Polich, 2007). ERPs from the recognition task (block 4) were not analyzed.

2.5. Statistical analysis

Behavioral data were analyzed with a t-test (Welch-test, due to heteroskedastic within-group variances) for the dependent variables error rate in the recognition task and recalled stimuli. The condition (instructed malingerers vs. control) was the group factor. Additionally, for exploration purposes, a 3x2 mixed-design ANOVA was conducted, with the response (correct vs. error vs. guess) as within-subject factor and the conditions as between-subject

factor. For this analysis, all participants without errors must be excluded for within-subject analysis to work, as they provide no reaction times. Also, for exploration purposes, we reported an ANOVA for differences in RT on the attention checks (the “eights” within the study phases).

For testing the differences in P1, N1, and P300 mean amplitudes a 3x2 mixed-design ANOVA was conducted, with the number of presentations of a stimulus (first vs. second vs. third) as within-subject factor and the condition (control vs. malingering) as between-subject factor. Dependent variables were the mean amplitudes of occipital electrodes for P1 and N1 effects, and mean amplitudes of the parietal electrodes for P300 effects. For the classical old/new effect a 2x2 mixed-design ANOVA was conducted, with novelty in study phase two (old vs. new) as within-subject factor and the condition (control vs. malingering) as between-subject factor.

Additional analyses on testing the differences in P1, N1, and P300 mean amplitudes were done by considering attention-based strategies as a third “group”. Thus, a 3x3 mixed-design ANOVA was conducted, with the number of presentations of a stimulus (first vs. second vs. third) as within-subject factor and the condition (control vs. response-based malingering vs. attention-based malingering) as between-subject factor. Dependent variables again were the mean amplitudes of occipital electrodes for P1 and N1 effects, and mean amplitudes of the parietal electrodes for P300 effects. For the classical old/new effect a 2x3 mixed-design ANOVA was conducted, with novelty in study phase two (old vs. new) as within-subject factor and the condition (control vs. response-based malingering vs. attention-based malingering) as between-subject factor.

For all analyses, the Greenhouse-Geisser correction was applied when necessary.

3. Results

Table 2 gives information about the number of included segments for each analysis. Descriptive statistics are listed in Table 3. ERP grand average curves for selected electrodes for both conditions are presented in Figures 2 to 4. As can be seen descriptively, frontal and occipital electrodes showed inverse effects, as occipital electrodes showed an early P1 within the time frame of 70-110 ms and N1 of 120-170, while frontal electrodes showed an early N1 and a later P1 component. Overall, signals from the same area of the scalp (frontal, parietal, occipital) were very similar and therefore were averaged. No differences between groups were found in latencies of N1, P1, and P300.

Figure 2: ERP grand averages for selected electrodes for the first study phase. Black waves indicate control group data (C), grey waves instructed malingerers data (IM).

Figure 3: ERP grand averages for selected electrodes for the added second study phase for stimuli presented two times. Black waves indicate control group data (C), grey waves instructed malingerers data (IM).

Figure 4: ERP grand averages for selected electrodes for the third study phase for stimuli presented three times. Black waves indicate control group data (C), grey waves instructed malingerers data (IM).

Table 2

Mean, standard error and confidence intervals of included segments per dependent variable

Dependent variable	Control			Instructed Malinger		
	<i>M</i>	<i>SE</i>	<i>95% CI</i>	<i>M</i>	<i>SE</i>	<i>95% CI</i>
Study phase 1						
Pres. 2x	22.91	0.4	[22.13,23.69]	23.68	0.33	[23.03,24.33]
Pres. 3x	22.82	0.37	[22.09,23.54]	23.24	0.429	[22.4,24.08]
Study Phase 2						
Pres. 1x	23.05	0.403	[22.26,23.83]	22.88	0.426	[22.05,23.71]
Pres. 3x	23	0.421	[22.17,23.83]	22.96	0.414	[22.15,23.77]
Study Phase 3						
Pres. 2x	22.77	0.518	[21.76,23.79]	23.64	0.31	[23.03,24.25]
Pres. 3x	22.73	0.422	[21.9,23.55]	22.56	0.469	[21.64,23.48]

Note: Presentation means how many times the items were presented to the participant in total. Within the first study phase, all items were new, however some of them were presented two times (study phase one and again in study phase three) some of them were presented three times (study phases one, two and three).

3.1. Statistical results of ERP data

3.1.1 Global analyses

For an overview of group effects see also Table 3. The 3x2-mixed-design ANOVA for P1 effects yielded no significant effects: number of presentations, $F(1.95, 90) = 2.58, p = .081$, condition, $F(1, 45) = 1.15, p = .289$, and interaction, $F(1.95, 90) = 0.237, p = .79$. The 3x2-mixed-design ANOVA for N1 effects yielded no significant effect for the number of presentations, $F(1.86, 90) = 0.12, p = .887$, but a significant effect of condition, $F(1, 45) = 4.80, p = .034, \eta^2_p = .096$. Instructed malingerers showed less negative N1 amplitudes. No interaction between both factors was found, $F(1.86, 90) = 2.032, p = .137$.

The 2x2-mixed-design ANOVA for the old/new effect yielded no effect of condition, $F(1, 45) = 0.321, p = .573$, and no interaction, $F(1, 45) = 0.088, p = .767$, but a significant

old/new effect, $F(1, 45) = 11.883, p < .001, \eta^2_p = .089$. That is, while we found an old/new effect, there was no difference between groups, and no changed old/new effect for malingerers.

The 3x2-mixed-design ANOVA for P300 study-phase repetition effects yielded a significant effect for the number of presentations, $F(1.69, 90) = 14.433, p < .001, \eta^2_p = .109$. Bonferroni-Holm post-hoc tests reveal that stimuli elicited more positive amplitudes on the second ($p < .001$) and third ($p < .001$) presentation compared to the first presentation. Additionally, we found a significant condition effect, $F(1, 45) = 5.339, p = .025, \eta^2_p = .068$, indicating that instructed malingerers produced less positive P300 amplitudes. The interaction between both factors was not significant, $F(1.66, 90) = 0.48, p = .62$. Therefore, the effects did not differ between groups.

3.1.2 Analyses considering attention-based strategies

Nine out of the 25 participants from the malingering group reported attention-based strategies (e.g. concentrating on or thinking of something else). The other 16 participants reported more response-based strategies (e.g. giving false answers, waiting a second before responding). We split the malingering group into a subgroup reporting such attention-based strategies (attention-based malingering) and one subgroup not reporting such strategies (response-based malingering). For an overview of these group effects see also Table 4. The 3x3-mixed-design ANOVA for P1 effects yielded no significant effects: number of presentations, $F(2, 88) = 1.339, p = .272$, condition, $F(2, 44) = 1.666, p = .195$, and interaction, $F(2, 88) = 0.391, p = .815$. The 3x3-mixed-design ANOVA for N1 also yielded no significant effects for number of presentations, $F(2, 88) = 0.494, p = .612$, or condition, $F(2, 44) = 1.624, p = .209$, and no interaction, $F(2, 88) = 1.032, p = .396$.

Table 3

Descriptive and test statistics of mean amplitudes, error rates and reaction times of global analyses

Variables	Control		Malinge		Test statistics		
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>t</i>	<i>F</i>
ERP Components							
P1 (70 – 110 ms)					1, 45		0.89
Pres. 1x	3.14	2.96	2.41	2.16			
Pres. 2x	2.90	3.49	2.00	2.04			
Pres. 3x	2.36	3.46	1.88	2.52			
N1 (120 – 170 ms)					1, 45		4.80*
Pres. 1x	-1.08	2.95	1.16	1.91			
Pres. 2x	-0.91	2.81	0.81	2.27			
Pres. 3x	-0.61	3.91	0.35	2.92			
P3 (220 – 500 ms)					1, 45		4.12*
Pres. 1x	3.01	2.16	2.34	1.94			
Pres. 2x	5.03	2.19	3.94	2.07			
Pres. 3x	5.66	2.98	3.95	3.09			
Old/new (220 – 500 ms)					1, 45		0.32
new	3.02	3.25	2.81	2.57			
old	4.78	2.65	4.29	2.05			
Reaction times					1, 38		1.71
RT correct	1000.82	179.61	987.20	799.49			
RT error	1341.24	725.49	962.26	670.42			
RT guess	1450.09	405.04	987.76	756.79			
Behavioral data							
Error rate (%)	2.64	2.85	46.08	24.99	24.71	8.62***	
Recalled	18.50	7.11	8.28	5.20	38.05	5.56***	

Note: * $p < .05$, ** $p < .01$, *** $p < .001$

Table 4

Descriptive and test statistics of mean amplitudes, error rates and reaction times of malingering subgroup analyses

Variables	response-based		attention-based		Test statistics	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>df</i>	<i>F</i>
ERP Components						
P1 (70 – 110 ms)					2, 44	1.34
Pres. 1x	2.97	2.31	1.17	1.71		
Pres. 2x	2.32	1.94	1.17	2.36		
Pres. 3x	2.11	2.23	1.12	2.80		
N1 (120 – 170 ms)					2, 44	1.62
Pres. 1x	0.83	2.32	0.94	1.49		
Pres. 2x	0.54	2.57	0.62	1.84		
Pres. 3x	-0.04	3.09	0.35	2.37		
P3 (220 – 500 ms)					2, 44	3.94*
Pres. 1x	2.88	1.84	1.64	1.98		
Pres. 2x	4.63	2.03	2.91	1.71		
Pres. 3x	4.26	3.16	3.57	2.99		
Old/new (220 – 500 ms)					2, 44	2.98 ⁺
new	3.64	2.29	1.33	2.49		
old	4.88	1.92	3.25	1.95		

Note: The control group also was a level within the analyses. For descriptive statistics of the control group see Table 3. ⁺ $p < .10$, * $p < .05$, ** $p < .01$, *** $p < .001$

The 2x3-mixed-design ANOVA for the P300 old/new effect yielded no significant effect of condition, $F(2, 44) = 2.983$, $p = .061$, $\eta^2_p = .076$, but a significant old/new effect, $F(1, 44) = 10.467$, $p < .001$, $\eta^2_p = .086$. The interaction was not significant, $F(2, 44) = 0.169$, $p = .845$. Thus, we found the old/new effect again, however, there was no significant difference between groups, even if attention- and response-based strategies were considered separately. Because the effect of condition was “marginally significant”, we conducted post-

hoc tests. These implied that there is a “marginally significant” difference between control and attention-based malingerers ($p = .067$), but a significant difference between both malingering subgroups ($p = .041$), indicating that attention-based malingerers showed overall lowest amplitudes compared to controls and response-based malingerers.

The 3x3-mixed-design ANOVA for P300 effects yielded a significant effect for the number of presentations, $F(1.64, 88) = 11.704, p < .001, \eta^2_p = .095$, and a significant effect of condition, $F(1, 45) = 3.936, p = .027, \eta^2_p = .098$. Post-hoc tests showed that stimuli elicited more positive P300 amplitudes on the subsequent presentations (second, $p < .001$; third, $p < .001$) compared to the first presentation. Attention-based instructed malingerers produced less positive P300 amplitudes compared to control participants ($p = .0014$). The expected interaction between both factors, however, was not significant, $F(1.64, 88) = 0.457, p = .767$. Therefore, the effects did not differ between groups if both strategies are considered separately.

3.2. Statistical results of behavioral data

For error rates in recognition, we found a statistically significant effect, $t(24.711) = 8.629, p < .001$, with instructed malingerers showing a mean error rate of nearly 50% and thus showing higher error rates than the control condition. Similarly, the t-test yielded a statistically significant effect for overall recalled stimuli, $t(38.049) = 5.56, p < .001$, with instructed malingerers recalling fewer stimuli. For analysis of reaction times, seven participants from the control condition had to be excluded because they did not produce any errors. The mixed-design ANOVA for reaction times yielded a statistically significant main effect for the response, $F(1.31, 76) = 10.721, p < .001, \eta^2_p = .024$. Post-hoc tests showed that participants were faster at correct responses compared to guess trials ($p = .006$). There was a significant interaction effect, $F(1.31, 76) = 7.109, p = .006, \eta^2_p = .016$. Post-hoc tests of differences between groups on each of the three levels of the response showed that there was

no difference between groups at responses that were correct ($p = .858$) or false ($p = .111$). Groups only differed in reaction times of guess responses ($p = .029$). The main effect of the condition was not statistically significant, $F(1, 38) = 1.713, p = .198$. See Table 3 and Figure 5 for an overview of reaction time results.

For the attention checks, the control group was the fastest ($M = 574.47, SD = 120.78$), followed by the attention-based malingerers ($M = 799.31, SD = 322.77$), and the response-based malingerers ($M = 940.31, SD = 420.68$). The ANOVA on the attention checks with the condition (control vs. response-based malingering vs. attention-based malingering) as between-subject factor yielded a significant main effect, $F(2, 44) = 7.4, p = .0017, \eta^2_p = .252$. Post-hoc comparisons revealed a significant difference between the control and response-based malingering group, $M_{diff} = 365.840, p = .0013$, meaning that the control group was faster than the response-based malingering group. The difference between the control and attention-based malingering group, $M_{diff} = 224.838, p = .141$, and the difference between the response- and attention-based malingering groups, $M_{diff} = -141.001, p = .488$, was not significant.

4. Discussion

The main goal was to study neurophysiological correlates that are associated with malingering. We focused on attention and memory recognition processes in addition to behavioral data. We changed the procedure of one of the most prominent and best-studied performance validity tests, the TOMM, to get neurophysiological data for the old/new effect and our study-phase repetition effects, without using additional tests. With behavioral and neurophysiological data, as well as the clinical background, a more reliable judgment on possible feigned memory behavior should be possible.

Figure 5: Means of reaction times between the two conditions. Error bars represent one standard error.

For the behavioral data, our results are in line with the hypotheses. We found that participants in the control condition generally produce fewer recognition errors, whereas instructed malingerers show error rates that are on average near chance, overdoing to an extent usually not found in the literature on PVTs. Additionally, data of the recall task showed that instructed malingerers remember fewer stimuli than participants in the control condition. This was expected, as nine instructed malingerers reported reduced attention to stimuli as a first strategy. However, it may also be that malingering instructions had a detrimental effect on retention as has recently been shown by Mangiulli, Van Oorsouw, Curci & Jellic (2019) in the context of a mock-crime malingering scenario. The second class of strategies was response-based e.g. to give false answers if they recognized a stimulus. Additionally, if a person feigns cognitive dysfunction, they need to not only focus on the task, but also on the

strategy of malingering. Under normal circumstances, participants should be able to only concentrate on learning the presented stimuli. Under malingering instructions or malingering motivation, participants have another primary task: producing results that imply they have cognitive deficits. Therefore, this should in turn decrease the overall attention to the task, as it binds cognitive resources. We found no differences for the occipital P1, but for the N1, thus confirming our hypothesis that malingerers have reduced visual attention to the task. When splitting the malingerers into a group of attention- and response-based strategies, we did not find any differences in these early components. Please note that by splitting the malingering group, power was reduced due to lower sample-sizes within groups.

We were able to replicate the P300 old/new effect; however, we found no differences between groups and no interaction effect. Thus, we were not able to replicate the absence of the P300 old/new effect in malingerers shown by Vagnini et al. (2008). We suppose that this difference occurs, because of task differences: While Vagnini et al.'s (2008) participants decided whether the item has been studied or not in the test phase, this response was not required in the critical study phase 2 of the present experiment. Therefore, the P300 old/new effect is possibly reduced due to malingering when an overt response is given (Vagnini et al., 2008), while the P300 old/new effect itself was preserved in malingerers when no overt response was required in the present study. In sum, this response pattern may suggest that intact memory can be addressed by apparent old/new effects in a study phase, while malingering reduces the old/new effect when an explicit memory response is required. The subsequent analysis addressed interindividual differences with respect to the usage of response- vs. attention-related malingering strategies. Here, we found a “marginally significant” group effect in the exploratory analysis when splitting the malingering group. Attention-based malingerers produced lower amplitudes. For the study-phase repetition effect, we found main effects in P300 amplitudes of group and number of presentations.

Participants in the control condition produced higher P300 amplitudes. Additionally, P300 amplitudes were larger in subsequent presentations.

The nature of attentional processes can explain differences in N1 amplitudes between conditions. Early processes at around 0-60 ms are mainly bottom-up driven and can barely be influenced by top-down processes that try to regulate visual attention (Gonzalez, Clark, Fan, Luck & Hillyard, 1994; Mangun, Hillyard & Luck, 1993). In contrast, N1 ERP amplitudes can be influenced by top-down processes (Gonzalez et al., 1994; Jeffreys & Axford, 1972; Mangun et al., 1993), which resulted in differences between inattentive and attentive participants (e.g. Mangun & Hillyard, 1990). Boksem et al. (2005), however, argued that the P1 primarily represents exogenous facilitation of early sensory processing, while the N1 represents additional top-down modulation of early sensory processing (e.g., Mangun & Hillyard, 1995). No effect on the P1 and a reduction of the N1 in malingerers can be well explained by assuming decreased attention to the task.

Similar effects were reported with a group of fatigued participants, assuming that fatigue results in reduced attention to the task (Boksem et al., 2005). Boksem et al. found that subjects reported increased aversion to continue the task with time on task. They described that this is a good indicator of mental fatigue (Boksem et al., 2005; Hockey, 1997). The reduced N1 amplitudes, however, may not only be an indicator of reduced attention due to mental fatigue but also due to reduced motivation to continue participation. Our N1 results thus may be alternatively explained by reduced motivation as well as decreased attentional resources due to the secondary goal of feigning cognitive impairment.

Also, in line with the attention-based strategy was that instructed malingerers produced lower P300 amplitudes to targets, as less attention should not only result in less positive amplitudes per se but also result in less memory of the presented stimuli (see e.g. Karis et al., 1984, Paller et al., 1988; Rushby et al., 2002). We did, however, not find any

interaction effects; however, we only expected a possible interaction within the malingering subgroup analyses. The lack of this interaction implies, that the effect did not differ between groups. This would mean, that the reduced P300 amplitudes are a result of overall decreased attention to the task, but not of reduced memory of a stimulus due to reduced attention on the past presentations. This in turn indicates that participants with attention-based malingering strategies also have memory about presented stimuli. When considering the malingering subgroups, however, we found that especially the participants with attention-based strategies showed reduced P300 amplitudes, while there was a descriptively lower difference between the control group and response-based malingerers. Note that the stimuli were rather simple in a way that memorizing the object shown was not hard. This could be of high value for future research and forensics. Future studies should examine our post-hoc comparisons more closely by instructing different malingering strategies.

Most studies focused on the development of new tests that can be used for ERP analysis and is largely focused on the oddball paradigm. However, behavioral data of the oddball task barely yields any information on malingering. Vagnini et al. (2008) used the TOMM and an additional old/new task with over 100 new stimuli to analyze P300 differences between groups. We extended the research by adapting a new learning phase within the procedure of the TOMM to study old/new and study-phase repetition effects. Additionally, we studied attention-based early ERP components and showed that they are promising indicators of malingering.

When compared to other results in the literature, our P1 (e.g. P1: 70-110 ms) and N1 (120-170 ms) occurred relatively early compared to the time windows typically described. For the P1 and N1, this likely is due to differences in tasks, as the time frames are not fixed. Mangun and Hillyard (1990), for example, also analyzed P1 effects in the time window of 80-140 ms and N1 effects in the time window of 140-220 ms in a divided visual attention

task. Hillyard & Anllo-Vento (1998) also reported P1 to appear at 80-130 and N1 to appear at about 120-200 ms after stimulus onset in a spatial attention task (Hillyard & Anllo-Vento, 1998, p. 782 and Figure 1). Similar, Boksem et al., 2005 find time windows of 100-160 ms for the P1 and 160-220 ms for the N1. More specifically, in repetition tasks very similar to our task, reliable latencies were reported. Olofsson and Polich (2007) presented participants with 72 pictures in a repetition task, reporting latencies of 80-120 ms for the P1 and 120-160 ms for the N1. In another study presenting line-drawing to participants, a N1 latency of 130-180 ms was reported (Groh-Bordin, Busch, Herrmann, & Zimmer, 2007). These previous reports indicate that the time windows of the present study are reasonable.

Also, our P300 effect was rather early, and there was no late positive effect. Our study-phase design, however, was similar to studies examining repetition effects. In this case, studies reported time frames of 220-350 ms for an early P300 (Fabiani et al., 1986; Kim et al., 2001; Noldy, et al., 1990; Segalowitz et al., 1997). In sum, the time frames of the present study were early, but not fundamentally different from time frames reported in other studies. Still, compared to Vagnini et al., (2008) we found no difference between control and malingering participants within the time frame of 400-650 ms.

Rather interesting is the result that malingerers with attention-based strategies were not slower than control participants, while malingerers with response-based strategies were. While this is surprising at first, it can be explained as response-based strategies include the behavioral delay of the response, which results in longer reaction times.

4.1. Implications for future research and applied testing of malingering detection

If done correctly and if not only one PVT is used (Slick et al., 1999), symptom validity assessment can be challenging, not only for neuropsychologists and other medical staff but especially the patient, in cases where the cognitive deficits are feigned. Assessment of symptom and performance validity, if done according to modern standards (e.g., Chafetz et

al., 2015; Heilbronner et al., 2009; Lippa, 2018) should be based on a variety of methods and approaches and, consequently, may be time-consuming. Developments like embedded measures of performance validity (cf., for a review, Larrabee, 2007) are one way of rendered validity assessment more time effective, another way would be the employment of behavioral observation and physiological measures taken during the evaluation. However, the employment of psychophysiological measures is still in its infancy and has not yet reached the stage of use for single case clinical or forensic decisions. For such single-subject classification, more research and possible different designs are necessary. Note that in our study only a total of 50 targets and 25 distractors were presented within the learning phases which results in more noisy data compared to studies with 100 or more trials.

4.2. Limitations

The main limitation of our study is the lack of data from real cognitive impaired people. For applied symptom validation, the pattern in ERP components of truly impaired participants needs to be known. This is essential, as false-positive classification has devastating consequences for impaired people. For P300 differences to be interpreted as an indicator of malingering (in this case, lower amplitudes in instructed malingerers), we must be sure that normal amplitudes are generated in people with valid impairment. However, latency differences from normal component waves could indicate a true deviation from normal functioning. For some brain injuries and illnesses, this seems to be the case. For example, longer P300 latencies were found in patients with temporal lobe epilepsy, but not in patients with idiopathic generalized epilepsy (e.g. Fukai, Motomura, Kobayashi, Asaba, & Sakai, 1990; Saito et al., 2001). For cognitive impairment, however, we need more focus on the comparison of malingered and real cognitive problems. In patients with mild cognitive impairment from Alzheimer's disease, reduced P300 amplitudes but longer P300 latencies were found (Bennys, Portet, Touchon, & Rondouin, 2007; Frodl et al., 2002; Gordon,

Kraiuhin, Harris, Meares, & Howson, 1986; Li, Tang, & Chen, 2016). In contrast, this was not the case with mild cognitive impairment from other domains, as they showed longer latencies than normal participants, but similar amplitudes (Bennys et al., 2007). Additionally, latency differences, even if statistically significant, differed on average about 20 - 50 ms between groups which is probably not sufficiently sensitive for single participant diagnostics (Bennys et al., 2007; Neal et al., 2019; Vagnini et al., 2008). For the N1 component, the picture is similar. In general, there are no statistically significant differences found in patients with Alzheimer's disease or mild cognitive impairment (Li et al., 2016; Saito et al., 2001). This was also shown for patients with multiple sclerosis and Parkinson's disease (Wang, Kuroiwa, Li, Wang, & Kamitani, 2001; Whelan et al., 2010). In contrast, for auditory tasks, patients with multiple sclerosis showed differences in N1 amplitudes (Whelan et al., 2010). Many of these findings showed different results which emphasizes the need for future research on differential diagnoses in the domain of detecting malingering.

5. Conclusion

We showed a possible way of more efficient multi-method detection of memory malingering with an already existing PVT. The results of our study confirmed the high potential in studying the P300 and N1 component for the detection of malingered behavior. We extended the research to examine ERP components that are associated with attention N1 that possibly explain differences in P300 effects between normal and instructed malingerers.

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