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Direct comparison of nocebo, deceptive placebo and open-label placebo effects on sustained visual attention

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ABSTRACT

Positive and negative expectations crucially shape how we perceive our surroundings, including our emotional and cognitive abilities. Prior work shows that cognitive abilities in different domains can be modulated by placebo or nocebo effects, in clinical cohorts, but also in the absence of disease. However, these studies show inconclusive results and do not directly compare different expectation modulations with each other. This pre-registered online study tested the effects of three types of expectations on cognitive performance in a visual attention task, using a mixed design. Participants (n = 197) completed this task before and after a written suggestion, which was information that white noise played during the task would either improve (deceptive placebo), improve through the placebo effect (open-label placebo), worsen (nocebo), or not affect (no suggestion) their focus and thus cognitive performance. In a complementary frequentist and Bayesian analysis framework, we observed evidence for learning effects such as faster reaction times or lower error rates from before to during the treatment. However, we found direct evidence of absence regarding any group-related differences. Interestingly, the nocebo group had lower impact ratings than both placebo conditions and the influence of the noise was rated as stronger compared to its expected influence at baseline. This work underscores the importance of distinguishing between subjective and objective effects when evaluating the influence of treatment suggestions on cognitive performance.

1. Introduction

Positive and negative expectations shape how we perceive our surroundings (Bingel, 2020): They dynamically impact our perception of medical treatments and therapies (Rief & Glombiewski, 2017) but also have downstream effects on wellbeing (Bräscher et al., 2022; Kleine-Borgmann et al., 2021; Shafir et al., 2023) and cognitive abilities (Foroughi et al., 2016; Kleine-Borgmann et al., 2021; Rozenkrantz et al., 2017; Turi et al., 2018) Emotional and cognitive wellbeing, in turn, are vital for daily functioning as well as educational and occupational success (Dyrbye et al., 2005; Lövdén et al., 2020).

Positive expectations can lead to placebo effects, defined as positive effects on health or treatment outcomes from a pharmacologically inert treatment (e.g., symptom relief from a sugar pill; Wager & Atlas, 2015). These positive effects have been demonstrated in many domains using deceptive placebos (DP), where participants believe a treatment to be pharmacologically active when in reality it is not. However, recent developments and growing ethical concerns have emerged regarding deceiving people about the nature of a placebo treatment. Recent research suggests that placebo effects also emerge even when people are aware of the treatment being inactive, so-called open-label placebos, which are given with the full knowledge of taking a sham treatment (OLP; Charlesworth et al., 2017; Colloca & Howick, 2018; Kaptchuk, 2018).

Nocebo effects, on the other hand, are fueled by negative expectations and can be defined as any negative effects resulting from a sham treatment (for example, the occurrence of negative symptoms, the worsening of symptoms, or the prevention of improvement; NOC; Bingel, 2020). In the worst case, nocebo effects can lead to stopping of vital treatments. Together, these powerful effects showcase how important the study of expectations is to improve people's overall well-being and health (Benedetti et al., 2022).

While expectations have been extensively studied in regard to improvement in many clinical conditions (Benedetti, 2008; Caliskan et al., 2024; Constantino et al., 2018; Cormier et al., 2016; Haanstra et al., 2012; Laferton et al., 2017), studies in healthy volunteers also hint

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at potential benefits of positive expectations in the absence of disease, for areas such as pain (Forsberg et al., 2017; Kunkel et al., 2025) or sleep (Suetsugi et al., 2007). Specifically, it has been suggested that treatment expectations and placebo effects might be harnessed to improve different aspects of cognitive performance. The rise in popularity of so-called 'smart drugs' such as modafinil or methylphenidate (Ritalin) to improve cognitive functioning (also called "cognitive enhancers") has sparked growing interest in utilizing the power of positive expectations without the occurrence of side effects associated with taking medication (Minzenberg & Carter, 2008; Turner et al., 2003; Zohny, 2015).

There are a handful of studies on the effects of expectations on cognitive performance, showing overall mixed results. Deceptive placebos improved IQ test results (Foroughi et al., 2016) and affected measures such as reaction time and working-memory (Ashor, 2011; Parong et al., 2022; Sinke et al., 2016). However, Katz et al. (2018) observed no improvement in cognitive tasks related to suggestions of improvement through training. Rabipour et al. (2020), Vodyanyk et al. (2021), and Tsai et al. (2018) all found no role of expectations or placebo effects on the (training of) different cognitive abilities. Moreover, many studies also only report effects on subjective (e.g. perceived improvement), but not objective parameters of cognitive functioning (e.g. actual task performance; Blokland, 2023; Winkler & Hermann, 2019). Open-label placebos only showed improved well-being but no effects on results of a medical exam (Kleine-Borgmann et al., 2021) or no effects at all in many different areas of cognitive performance (Hartmann et al., 2023).

The authors of the latter study argue that expectation-related effects (albeit subjective more than objective ones) are likely strongly affected by an individuals' motivation or desire for these changes and their meaning, as well as the attribution of changes to the received treatment, which aligns with the expectancy-value theory (Wigfield & Cambria, 2010). In line with this theory, expectations might influence processes like attention or arousal, which, in turn, affect cognition (Denkinger et al., 2021). This theory could also explain the above mixed findings in the cognitive domain, as healthy individuals might not see as much need to improve their abilities in some domains as compared to others. On the other hand, research suggests that cognitive enhancers are increasingly being used among healthy individuals, mainly students without any diagnosed cognitive disorders, to increase their alertness, concentration, memory, or performance during examinations or when studying (e.g., Husain & Mehta, 2011). Furthermore, the expectancy-value theory is particularly relevant for expectation-based interventions in clinical populations with limited awareness of their cognitive deficits, such as stroke patients experiencing hemineglect that impairs their visual attention. If patients are unaware of their visual attention deficits, they are unlikely to anticipate significant treatment effects for a condition they do not recognize (Kerkhoff, 2001; Kerkhoff & Schenk, 2012).

Some studies have shown expectation effects specifically on visual attention: Placebo effects reduced visual avoidance of negative affective stimuli (Gremsl et al., 2018; Schienle et al., 2014, 2016) and enhanced performance on a visual search task (Colagiuri et al., 2011). A placebo video game training session implied to make participants perform better increased visual attentional performance (Tiraboschi et al., 2019; but see Joessel et al., 2025 for a failed replication). In contrast, nocebo effects reduced performance in the same visual search task (Colagiuri et al., 2011). Similarly, a recent study by Piedimonte et al. (2024) found placebo-related increases and nocebo-related decreases in visual accuracy were even accompanied by corresponding changes in the event-related potential P300 component. Interestingly, two studies on placebo and nocebo effects on visual attention suggest that negative expectations may sometimes also lead to compensatory behavior which may in some cases even improve task performance (Höfler et al., 2018, 2019). Höfler et al. (2019) found that participants in the nocebo condition, despite being told their attention to the left side of their visual field would decrease, shifted their visual attention to the left and found targets more quickly in high visual load search tasks. This suggests that negative expectations may not always impair performance but could instead lead to compensatory mechanisms, such as increased effort or deliberate attention shifts.

In sum, there is mixed evidence whether positive and negative expectations are able to influence cognitive abilities in general, and visual attention specifically. These studies paint a rather heterogeneous picture, with some studies finding evidence for placebo and nocebo effects, others only finding effects on subjective parameters, and some reporting limited to no evidence for expectation effects. Many studies also only investigate one or maximum two types of expectations, hampering direct comparisons between these effects. Especially evidence for subjective measures is interesting to consider in light of demand characteristics, i.e. when participants know about a study's goal or hypothesis and change their behavior because of this knowledge (see e.g., Nichols & Maner, 2008 or the Hawthorne Effect; Adair, 1984). In placebo studies, this changed behavior could lead to exaggeration of expectation effects, while it might lead to compensatory behavior in nocebo studies (e.g., participants trying harder to overcome their negative expectations; see also the John Henry Effect). A recent meta-analysis found that such demand characteristics are far from negligible and may contribute to biased results, but vary strongly between hypothesis-consistent and hypothesis-inconsistent behavior (Coles et al., 2025).

To address some limitations of previous research like the lack of studies directly comparing open-label and deceptive placebos alongside nocebo effects within a single study (e.g., Höfler et al., 2019) and to contribute to a deeper understanding of how different positive and negative expectations affect attention, the present study investigated the effects of three types of expectations on cognitive performance in a visual attention task, using a mixed design. Participants completed this task before and after a written suggestion, which contained information that white noise the participants heard during the task would either improve (DP or OLP), worsen (NOC), or not affect (CTR) their focus and thus cognitive performance.

In our preregistration and in line with previous research, we initially hypothesized that 1) the deceptive placebo suggestion would improve performance compared to the no suggestion condition (DP > CTR), and that 2) the open-label placebo suggestion would improve performance compared to the no suggestion condition, but less so compared to the deceptive placebo condition (DP > OLP). For the third hypothesis, we remained non-directional and hypothesized that 3) the nocebo suggestion would either a) worsen performance (nocebo hypothesis, NOC < CTR) or b) improve performance (compensation hypothesis, NOC > CTR).

2. Materials and methods

2.1. Data and code availability statement

The data and code needed to run all analyses and reproduce the figures as well as the code for the Pavlovia paradigm and an example video of the paradigm (deceptive placebo condition) can be found on our Open Science Framework (OSF) project https://osf.io/rxzch/.

2.2. Preregistration

We report how we determined our sample size, all data exclusions, all manipulations, and all measures in the study. This study, including hypotheses and analysis plan, was preregistered on the OSF prior to any creation of data (https://osf.io/9emr3/). In the following methods and results, we clearly separate preregistered procedures and analyses from those added post hoc.

2.3. Participants

Recruitment and online data collection took place from September 2023 to July 2024. Participants were recruited via email lists, existing participant databases, and postings on social media. Participants had to have access to headphones and a touchscreen device (smartphone or tablet). Apart from that, there were no exclusion criteria. The study was conducted in accordance with the declaration of Helsinki (World Medical Association, 2013) and the ethics committee of the University of Graz approved the study procedure (ethics approval code: GZ. 39/ 140/ 63 ex 2022/23).

An a priori power analysis (repeated measures, within-between interaction, four groups, two measurements, power = 0.80, alpha = 0.05, partial eta squared = 0.01) indicated a needed sample size of 276 (around 69 participants in each group, allowing for slight group imbalances). To account for dropouts and exclusions, we aimed to stop data collection as soon as $n \geq 300$. We collected data of 303 participants but, as preregistered, excluded participants with more than 50 % of trials without a correct response within 5000 ms ($n = 106$, of whom $n = 94$ dropped out before group assignment). The final sample thus comprised 197 participants (135 female, 45 male, 7 diverse, 10 preferred not to disclose): 54 in the deceptive placebo condition ($n = 6$ dropped out after group assignment), 52 in the open-label placebo condition ($n = 1$ dropped out after group assignment), 49 in the nocebo condition ($n = 0$ dropped out after group assignment, $n = 1$ excluded due to an error rate above 50 %), and 42 in the control condition ($n = 4$ dropped out after group assignment). The mean age (SD) was 29.2 years (10.4 years). Age and gender distributions are summarized for each group separately in Table 1.

Table 1
Descriptive data (M = mean, SD = standard deviation) for age (in years) and gender for all four groups and overall.

Group	Age (years)	Gender (n)
CTR	$M = 30.2$; $SD = 13.2$	26 female, 13 male, 2 diverse, 1 n.a.
OLP	$M = 28.3$; $SD = 8.6$	36 female, 13 male, 2 diverse, 1 n.a.
DP	$M = 28.6$; $SD = 9.5$	37 female, 10 male, 0 diverse, 7 n.a.
NOC	$M = 29.8$; $SD = 10.3$	36 female, 9 male, 3 diverse, 1 n.a.
Overall	$M = 29.2$; $SD = 10.4$	135 female, 45 male, 7 diverse, 10 n.a.

Note. CTR = no suggestion, OLP = open-label-placebo, DP = deceptive placebo, NOC = nocebo, n.a. = not available. There was no significant effect of group (i.e., condition) for age ($p = .789$) or gender ($p = .512$).

2.4. Procedure

The study was conducted online, with no personnel interacting directly with participants. Participants opened the study invite link and were directed to a page where they received basic information about the study. The participants were told that the study investigated how noises affect focus in a visual attention task.

After receiving information about the study procedure and data protection guidelines, participants were asked to check two boxes to (1) provide their consent for participation and (2) confirm that they understood they could withdraw from the study at any time. They were then instructed to connect their headphones to their device and hold the device horizontally before being redirected to the online Pavlovia (version 2023.1.3; created using PsychoPy; Peirce et al., 2019) environment (see Fig. 1). We pretested the paradigm on multiple touchscreen devices with varying operating systems (Android and iOS), aspect ratios (ranging from 4:3 to 21:9), and screen resolutions. Square visual stimuli (bird images with a resolution of 720 × 720 pixels) were displayed centrally on the screen using the full height of the screen. Response buttons were positioned at 25 % (left button) and 75 % (right button) of the screen's horizontal width. On all tested devices, the paradigm was displayed as intended.

At the beginning of the Pavlovia paradigm, participants were introduced to the four stimuli (photos of four different birds: crow, gull, penguin, and tit) and the corresponding buttons they needed to press as quickly and accurately as possible in response to each bird stimulus. The left button corresponded to "corn" for the gull and tit, while the right button corresponded to "carrot" for the crow and penguin. These bird/ food pairings were fictional, and alliterations were used to facilitate memorization (German: carrot = "**K**arotte," king penguin = "**K**önigspinguin," crow = "**K**rähe," corn = "**M**ais," gull = "**M**öwe," tit = "**M**eise"). Participants were given unlimited time to memorize each association between bird (stimulus) and food (response) before proceeding and confirmed having memorized the association by pressing the corresponding (food) button.

Subsequently, participants completed a baseline measurement of the task without any auditory stimulation. This phase consisted of 44 trials, with the first four trials serving as practice trials and being excluded from the analysis. In each trial, one of four bird images appeared at the center of the screen. Depending on the image, participants were required to tap either a left- or right-sided button, representing the specific type of food preferred by the displayed bird (carrot or corn). If an incorrect button was tapped, a cartoon speech bubble with the word "Disgusting!" appeared above the bird, and the stimulus remained on the screen until the participant selected the correct button.

Subsequently, participants were randomly assigned to one of four between-subjects experimental conditions: 1) deceptive placebo, 2) open-label placebo, 3) nocebo, and 4) suggestion of no effect (i.e., control group). In the deceptive placebo condition, it was suggested to the participants that the sound they were about to hear can improve focus. In the open-label placebo condition, participants were also told about improvement of focus, but through the mechanism of the placebo effect. In the nocebo condition, they were told that the noise would worsen their focus and in the control condition, they were told that the sounds would not affect focus. Participants of the deceptive placebo condition and participants of the nocebo condition were not informed that the auditory stimulation (i.e., treatment) actually was a sham treatment.

After, participants again completed 44 trials of the same task, this time with auditory stimulation (the first four trials were again discarded).

We also measured people's expectations regarding the impact of the auditory stimulation on their performance before ("How do you expect the auditory stimulation to affect your performance?") and after the main task ("How did the auditory stimulation affect your performance?"), which were rated on a 0–100 slider from extreme worsening (0) over no change (50) to extreme improvement (100). At the end, participants provided information about their gender and age.

The whole study took around 5–10 min to complete and participants did not receive any compensation for their participation.

2.5. Data acquisition and analysis

In general, we used the standard $p < .05$ criteria for determining if the ANOVA and the post hoc tests suggest that the results are significantly different from those expected if the null hypothesis were correct. The post-hoc Bonferroni-Holm test was used to adjust for multiple comparisons. Analyses were conducted using JASP (version 0.95.2.0; JASP Team, 2025).

2.5.1. Preregistered analyses

Our preregistered dependent variables were mean reaction time (in ms) for trials which were correctly responded to within 5000 ms and error rate (% incorrect responses). For each participant, we calculated the average reaction time for all correct trials with a reaction time no longer than 5000 ms with the treatment (auditory stimulation) and without the treatment (baseline without auditory stimulation). We also calculated the percentage of incorrect trials for trials with and without the treatment. We analyzed the data in two 4 × 2 mixed ANOVAs, with the between-subjects factor *group* (deceptive, open-label, nocebo, no suggestion) and the within-subject factor *time* (baseline, treatment).

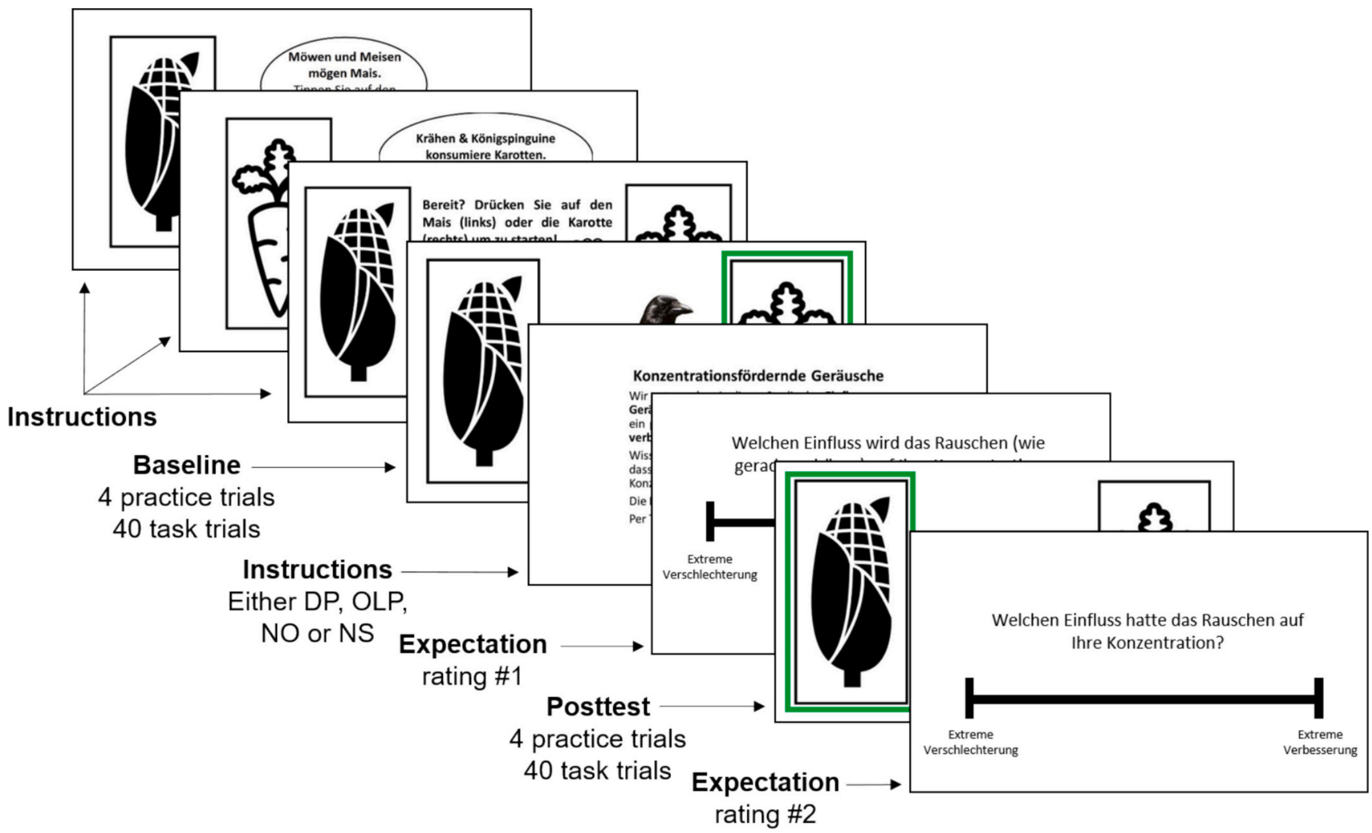

Fig. 1. Overview of the task structure. Abbreviations: DP = deceptive placebo, OLP = open-label placebo, NO = nocebo, NS = no suggestion. An example video as well as the Pavlovia paradigm are available in the OSF project: https://osf.io/rxzch/.

2.5.2. Exploratory analyses

To investigate direct relative evidence for the null compared to the alternative hypotheses, we repeated our above main frequentist analyses in a Bayesian framework. The impact ratings before (expected) and after (experienced) the main task were our third, exploratory dependent variable. We again analyzed the data in a 4 × 2 mixed ANOVA (both frequentist and Bayesian), with the between-subjects factor *group* (deceptive, open-label, nocebo, no suggestion) and the within-subject factor *time* (baseline, treatment).

We used Bayesian repeated-measures ANOVAs with a standard prior of 0.5 as the effect size (indicating a 50 % chance to observe an effect size between −1 and 1 in the fixed effects; e.g. Rouder et al., 2009). Note that Bayesian tests produce a Bayes Factor comparing the relative evidence between the alternative and null hypothesis (BF_{10}, H1 vs. H0; Mac Giolla & Ly, 2019). A $BF_{10} < 3$ has been suggested to indicate weak evidence, a $BF_{10} > 3$ positive evidence, and $BF_{10} > 150$ very strong evidence for the alternative compared to the null hypothesis (Jarosz & Wiley, 2014). Evidence for the null compared to the alternative hypothesis (BF_{01}, H0 vs. H1) was computed as $BF_{01} = 1/BF_{10}$.

3. Results

3.1. Preregistered analyses

For reaction time, only the effect of *time* [$F(1,187) = 264.19$, $p < .001$, $\eta^2 = .586$], but neither the effect of *group* [$F(3,187) = 0.49$, $p = .691$, $\eta^2 = .008$], nor their interaction [$F(3,187) = 0.23$, $p = .876$, $\eta^2 = .004$] was significant. The effect of *time* was characterized by a faster reaction time during the treatment ($M = 666$ ms, $SD = 173$ ms) than during the baseline assessment ($M = 845$ ms, $SD = 220$ ms; see Table 1 & Fig. 2).

For the error rate, neither of the two main effects nor their interaction had a significant effect [*group*: $F(3,187) = 0.49$, $p = .689$, $\eta^2 = .008$; *time*: $F(1,187) = 3.47$, $p = .064$, $\eta^2 = .018$; *group x time*: $F(3,187) = 0.15$, $p = .928$, $\eta^2 = .002$; see Table 2 & Fig. 3].

3.2. Exploratory analyses

For the self-reported impact of the treatment (pre: expected, post: perceived) ratings, there was an effect of *group* [$F(3,179) = 4.05$, $p = .008$, $\eta^2 = .064$]. This effect was characterized by significantly lower ratings in the NOC group compared to both placebo conditions [NOC - DP: $t(179) = 3.25$, $p_{Holm} = .008$, $d = 0.53$; NOC - OLP: $t(179) = 2.67$, $p_{Holm} = .042$, $d = 0.44$] Also, the effect of *time* was significant [$F(1,179) = 8.00$, $p = .005$, $\eta^2 = .043$] and characterized by an overall more positively experienced impact of the noise (post: $M = 52.41$, $SD = 18.70$), compared to its expected impact (pre: $M = 47.81$, $SD = 14.81$). The interaction effect was not significant [$F(3,179) = 0.27$, $p = .846$, $\eta^2 = .005$; see Fig. 4].

The Bayesian analyses largely mirrored and confirmed the (null) results of the frequentist analyses. For reaction time, only the effect of *time* showed very strong evidence for the alternative hypothesis ($BF_{10} > 150$), while the effects of *group* ($BF_{01} = 11.12$) and *group x time* ($BF_{01} = 51.54$) showed positive evidence for the null hypothesis.

For the error rate, there was weak evidence for the null hypothesis for the effect of *time* ($BF_{01} = 2.34$), positive evidence for the null hypothesis for the *group* effect ($BF_{01} = 20.40$), and strong evidence for the null hypothesis for the *group x time* interaction ($BF_{01} = 303.11$).

For the impact ratings, there was positive evidence for a main effect of *time* (higher impact post vs. pre; $BF_{10} = 4.68$), weak evidence for a main effect of *group* ($BF_{10} = 2.63$) and positive evidence for the null hypothesis regarding an interaction between *time* x *group* ($BF_{01} = 9.69$). Post-hoc comparisons showed that there was a significant difference between the DP and the NOC groups ($BF_{10} = 125.68$) and between the

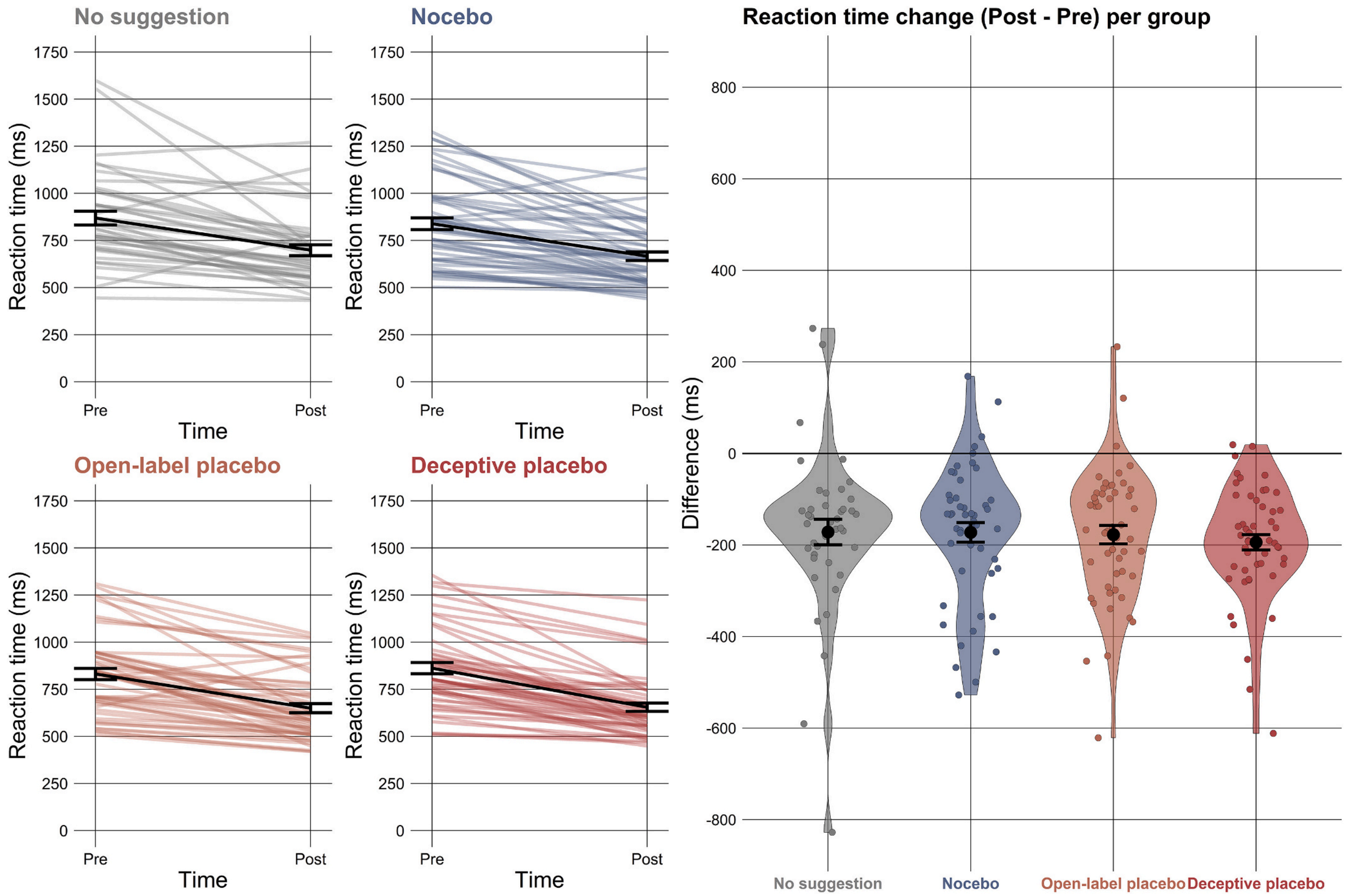

Fig. 2. Reaction time results (in milliseconds). Only a significant main effect of time emerged, but no group differences or interaction effects between group and time. Error bars show standard errors. Left: Black lines display group means. Colored lines display data of participants (gray: No suggestion, blue: nocebo, orange: open label placebo, red: deceptive placebo). Right: Violin plots for reaction time change (post – pre). Colored dots (jittered horizontally to avoid overplotting): participant data. Black dots: group mean. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 2

Descriptive data (*M* = mean, *SD* = standard deviation) for reaction time (in ms) and error rate (in %) at both times (Pre, Post) and overall as well as for all four groups and overall.

Group	Reaction time (ms)			Error rate (%)		
	Pre	Post	Overall	Pre	Post	Overall
CTR	*M* = 870 *SD* = 241	*M* = 698 *SD* = 189	*M* = 784 *SD* = 196	*M* = 5.1 *SD* = 5.8	*M* = 4.4 *SD* = 5.5	*M* = 4.8 *SD* = 4.7
OLP	*M* = 827 *SD* = 214	*M* = 650 *SD* = 175	*M* = 739 *SD* = 181	*M* = 5.9 *SD* = 6.7	*M* = 4.7 *SD* = 5.9	*M* = 5.3 *SD* = 5.6
DP	*M* = 845 *SD* = 211	*M* = 655 *SD* = 167	*M* = 752 *SD* = 180	*M* = 5.2 *SD* = 6.3	*M* = 4.1 *SD* = 4.5	*M* = 4.7 *SD* = 4.2
NOC	*M* = 839 *SD* = 223	*M* = 667 *SD* = 163	*M* = 753 *SD* = 180	*M* = 6.1 *SD* = 8.8	*M* = 5.7 *SD* = 7.5	*M* = 5.9 *SD* = 7.4
Overall	*M* = 845 *SD* = 220	*M* = 666 *SD* = 173	*M* = 756 *SD* = 183	*M* = 5.6 *SD* = 7.0	*M* = 4.7 *SD* = 5.9	*M* = 5.2 *SD* = 5.6

Note. CTR = no suggestion, OLP = open-label-placebo, DP = deceptive placebo, NOC = nocebo.

OLP and NOC groups (BF_{10} = 11.23). The DP and OLP groups indicated a stronger (positive) impact of the white noise than the NOC group independent of time. All other comparisons showed more evidence for the null hypothesis or only anecdotal evidence for the alternative hypothesis.

4. Discussion

This preregistered study tested the effects of three types of expectation-based interventions on cognitive performance in a visual attention task, using a mixed design: Four groups all conducted the same baseline measures of a visual attention task before all participants conducted the task again while being exposed to the same white noise. By altering only information about the suggested effect of the noise, we were able to directly compare the effects of an open-label placebo, a deceptive placebo and a nocebo suggestion in the same participants, using the same paradigm and stimuli.

We observed learning effects, i.e., very strong evidence for faster reaction times and weak evidence for lower error rates from before to during the treatment. These observations are common and to be expected in mixed designs where participants complete the same task twice (e.g., Hartmann et al., 2023). We expected these learning effects to differ between groups and that the task performance would increase more in the placebo groups while increasing less or even decrease in the nocebo group. Contrary to our a priori hypotheses, we found positive evidence of absence regarding any group-related effects on the more objective performance-based parameters reaction time and error rate. This is in line with previous studies showing no or contradicting effects of suggestions on cognitive performance or visual attention (Hartmann et al., 2023; Höfler et al., 2019; Potthoff & Schienle, 2025).

Interestingly, the subjective (i.e., self-report) measure painted a

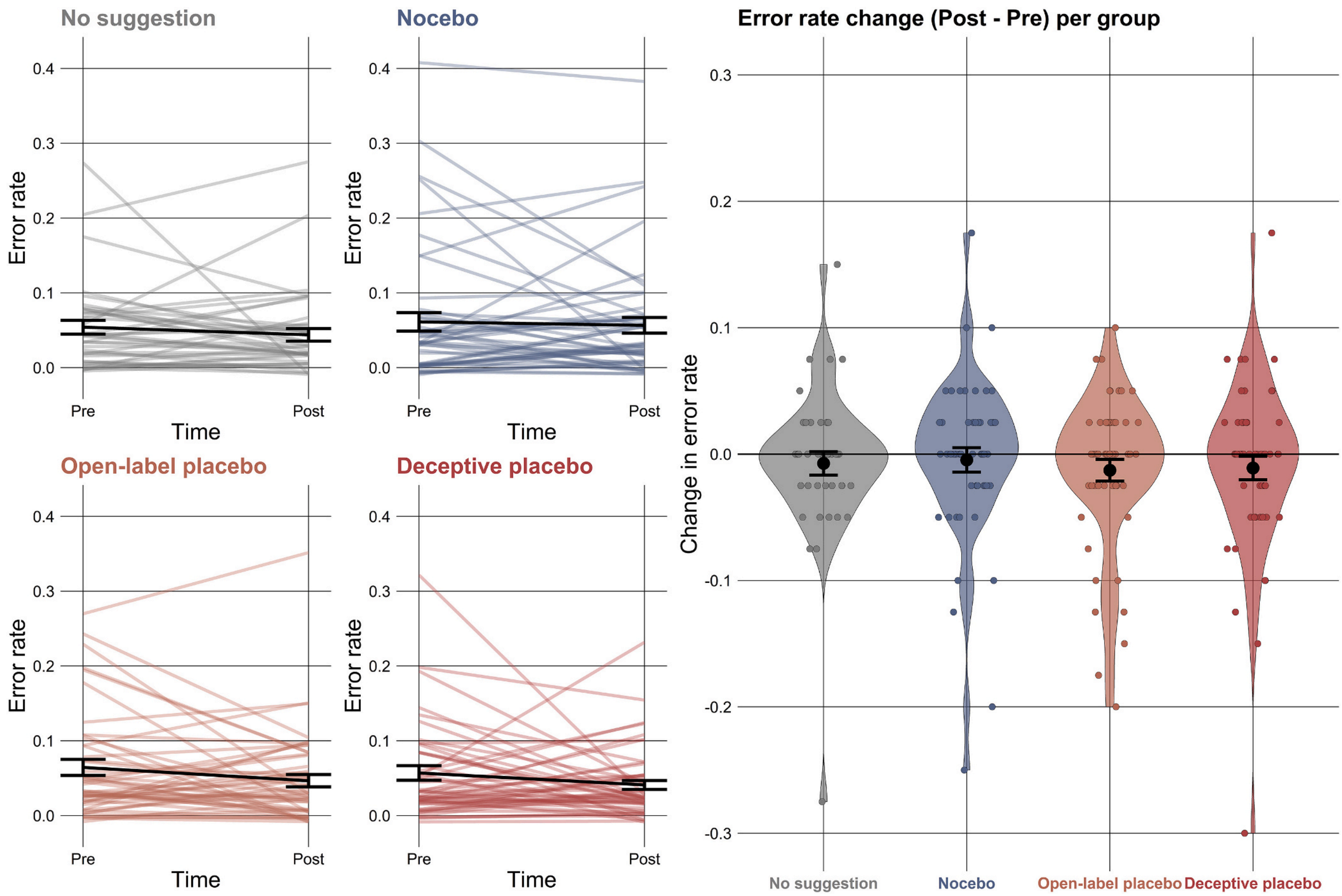

Fig. 3. Error rate. Error bars show standard errors. Left: Black lines display group means. Colored lines display data of participants (jittered to avoid overplotting; gray: No suggestion, blue: nocebo, orange: open label placebo, red: deceptive placebo). Neither of the two main effects nor their interaction had a significant effect. Right: Violin plots for error rate change (post – pre). Colored dots (jittered horizontally to avoid overplotting): participant data. Black dots: group mean. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

slightly different picture. The nocebo group rated the impact of the noise to improve their task performance lower than both the placebo and open-label placebo conditions, independent of time. This pattern in the self-report data suggests that participants adjusted their expectations in line with the content of the suggestion (as in Blokland, 2023; Winkler & Hermann, 2019). The consistently lower impact ratings in the nocebo group indicate that negatively framed information influenced subjective evaluations, despite the treatment-related stimulus (i.e., white noise) being identical across groups. Notably, the more negative perception of the white noise's effect on task performance persisted even after participants had direct experience with the task, suggesting that subjectively perceived nocebo effects may be resistant to disconfirmation even when the anticipated negative outcome does not occur. On the other hand, these effects might also be explained by hypothesis-consistent demand characteristics, where participants purposefully gave subjective responses in line with negative expectations induced by the instructions.

It is, however, interesting to note the rather large between-participant spread in the expected impact, particularly in the two deceptive groups (DP and NOC). This could be due to the nature of the study: As participants conducted the task online, the written task instructions were minimal, there was no face-to-face interaction with trained study personnel or physicians (Seewald & Rief, 2024), and we did not employ targeted conditioning of placebo/nocebo effects (Spisak et al., 2025). While this study design could have reduced expectations in some participants, many in-person studies report similar variation, with placebo responses ranging from zero to strong. Future studies could focus more on individual differences (Corsi & Colloca, 2017) and what context factors are necessary to elicit strong placebo/nocebo effects, especially in online studies.

Moreover, the influence of the noise was rated as stronger compared to its expected influence at baseline, independent of group, with the Bayesian analyses showing positive evidence for this effect. On the one hand, this finding is surprising given that previous (open-label) placebo studies have observed disappointment effects characterized by lower impact ratings after the treatment compared to the expected impact (Schienle et al., 2022). On the other hand, it is possible that participants merely attributed their improved performance characterized by fewer errors and a faster reaction time to the white noise rather than to practice effects. Future research should investigate whether the self-reported positive effect of the white noise persists even if exhaustion effects occur in prolonged visual attention tasks or if (blocks of) trials alternate between white noise and silent conditions.

This study has some limitations that have to be mentioned. First of all, the noise was not played continuously, but paused during the correct response (i.e., after each trial). This approach could have potentially hampered effects. However, participants across all groups reported greater perceived compared to expected impact. This suggests that participants were not distracted by the paused noise. Second, our sample was collected through convenience and is not representative of the general population. The sample of male participants was too small to analyse and interpret any effects of gender in a meaningful way. Future work should try to replicate our findings in a larger sample, which would also allow additional analyses of age or gender. Finally, the exclusion of more than one-third of the initial sample is a significant limitation that has to be discussed. The majority of exclusions were due to participants

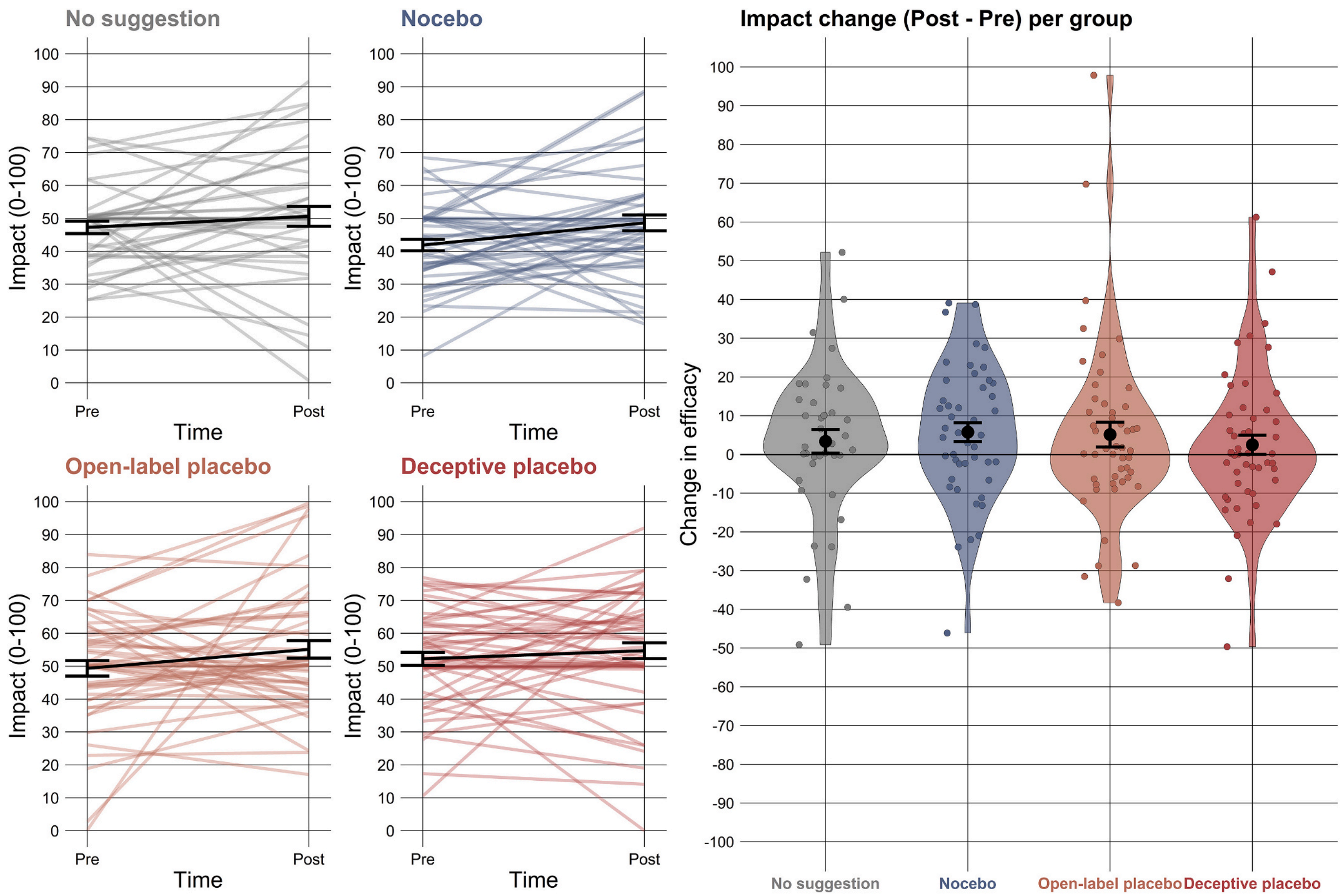

Fig. 4. Expected/perceived impact [extreme worsening (0) over no change (50) to extreme improvement (100)]. Bars show standard errors. Left: Black lines display group means. Colored lines display data of participants (jittered to avoid overplotting; gray: No suggestion, blue: nocebo, orange: open label placebo, red: deceptive placebo). Right: Violin plots for impact change (post: perceived – pre: expected). Colored dots (jittered horizontally to avoid overplotting): participant data. Black dots: group mean. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

dropping out before group assignment, rather than task difficulty. This suggests that the task itself was not overly demanding, as evidenced by the comparably low error rates and fast response times among the final sample. Importantly, the vast majority of dropouts was not related to group-specific factors, such as skepticism toward the open-label placebo suggestion or reluctance to experience nocebo effects. To address this limitation, future studies should focus on strategies to enhance participant engagement, particularly in online settings.

In sum, this study underscores the importance of distinguishing between subjective and objective effects when evaluating the influence of treatment suggestions on cognitive performance.

CRediT authorship contribution statement

Jonas Potthoff: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Helena Hartmann:** Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Project administration, Methodology, Investigation, Formal analysis, Conceptualization.

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Declaration of competing interest

The authors declare that they have no financial interests or potential conflicts of interest.

Data availability

Data has been made available in the Open Science Framework.

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