Does Exposure to Pictures of Nature Boost Attentional Control in the Stroop task?

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Abstract

Attention Restoration Theory (ART) argues that natural environments, or stimuli associated with natural environments, can restore reduced inhibitory capacity. ART has received support from studies showing that the Stroop congruency effect (incongruent – congruent trial RTs) is reduced following exposure to nature. Given that the Stroop congruency effect conflates interference (inhibition), facilitation and response contingency effects, these previous studies have not tested the central tenet of ART. Therefore, the present study was designed to a) unambiguously assess the extent to which exposure to pictures of nature (vs. control pictures) reduces Stroop interference (incongruent – color-neutral trial RTs; i.e., prima facie evidence for restored inhibition/attentional control); b) shed additional light on cognitive processes involved in this reduction. In line with past studies, pictures of nature were perceived as more restorative compared to control pictures. However, despite being appropriately powered and showing typical Stroop findings, the present study failed to provide evidence that exposure to these restorative pictures (as opposed to control pictures) actually reduces Stroop interference: Bayesian evidence against this reduction was provided in both errors and in reaction times and this conclusion was also reinforced by sequential analyses. Consequently, the present results indicate that exposing individuals to pictures of nature is not effective for replenishing inhibitory control in the Stroop task.

Key words: environmental design, attentional control, Stroop interference, Semantic conflict, Response conflict

1. Introduction

Attention Restoration Theory (ART, Kaplan, 1995) argues that natural environments or stimuli associated with natural environments can restore *directed attention* (i.e., voluntary and effortful attention required to inhibit distracting stimuli; see James, 1892) that is prone to fatigue. ART suggests that natural stimuli are intrinsically fascinating in a way that engages a type of attention that does not require cognitive effort and that the engagement of this type of attention permits the concurrent replenishment of directed attention (Kaplan, 1995).

In addition to assessing the robustness of this restorative effect, recent meta-analyses (Ohly et al., 2016; Stevenson et al., 2018) attempted to quantify the extent to which different components of directed attention are sensitive to the aforementioned restoration effect. Stevenson and colleagues (2018) reported a small but positive effect of exposure to nature on *attentional control*. Since this component of directed attention reflects inhibition of irrelevant or distracting stimuli (see e.g., Jackson & Balota, 2013), the evidence for its replenishment is particularly important for the test of ART.

Nevertheless, a closer look at the effect reported in the meta-analysis reveals that it includes studies (see Stevenson et al., 2018, Table 5) using the Stroop task (Stroop, 1935). This "prototypical inhibition task" (Miyake et al., 2000, p. 57) requires participants to name or classify the color of the font in which a word is presented whilst ignoring the meaning of the word itself. In line with ART, *the Stroop effect* (i.e., the difference in color-identification times for *color-incongruent* and *color-congruent* items; $BLUE_{\text{yellow}}$–$BLUE_{\text{blue}}$) was shown to be reduced in these studies following exposure to natural environments or stimuli associated with natural environments.

Although a reduced magnitude of this overall Stroop or *congruency effect* is often equated with boosted attentional control (e.g., Jackson & Balota, 2013; Stevenson et al., 2018), it is important to understand that in the absence of a color-neutral baseline (e.g., non-color word

"DEAL" displayed in yellow, hereafter *DEAL*$_{yellow}$), *interference* produced by color-incongruent items – the reduction of which constitutes prima facie evidence for increased attentional control – is confounded with an opposing *facilitation* effect produced by color-congruent items (MacLeod, 1991; Parris et al., 2021, see Figure 1).

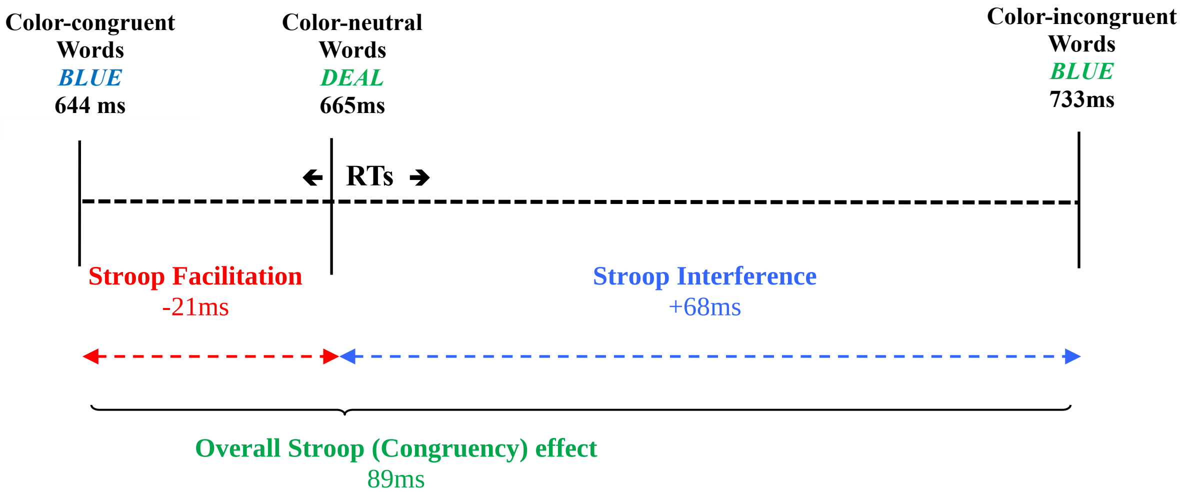

Figure 1. *The contribution of Stroop facilitation (Dalrymple-Alford, & Budayr, 1966) vs. Stroop interference (Stroop, 1935) to the overall Stroop (congruency) effect (data from Experiment 2 of Augustinova et al., 2019).*

Without a color-neutral baseline, the difference between color-incongruent and color-congruent trials actually represents "(…) the sum of facilitation and interference, each in unknown amounts" (MacLeod, 1991, p.168). Moreover, facilitation can actually increase substantially – thereby reducing the overall Stroop effect – when, for instance, experimental setups encourage contingent associative learning between color-stimuli and responses (Schmidt, 2013). Given that none of the existing studies of attention restoration compared performance on incongruent trials to color-neutral trials, the extent to which exposure to nature reduces interference rather than boosts facilitation and/or contingent responding in the Stroop task is at this point unknown. Since inhibition – which would only affect interference – plays a central role in ART, a direct test of the theory is whether exposure to nature actually affects this specific component of the overall Stroop effect (see Figure 1). Therefore, the present study was aimed at addressing this effect unambiguously.

To this end, the present study measured Stroop interference ($BLUE_{\text{yellow}}$– $DEAL_{\text{yellow}}$), in which response contingency was controlled, before and after the exposure to stimuli associated with natural environments. Since Stevenson and colleagues (2018) found no significant difference in effect sizes between actual and virtual exposures suggesting that even a simple exposure to pictures of nature can have a restorative effect on attentional control, pictures of a natural (vs. a control) environment as per Berto (2005; see also Neilson et al., 2021) were used in the present study. Unlike in Berto (2005), pictures of urban environments were not included in the present study, and the Stroop task was used instead of the Sustained Attention to Response Task.

Stevenson et al.' (2018) noted that the cognitive processes underlying attention restoration are still rather poorly understood. To address this point, the present study employed the *two-to-one Stroop paradigm* (Burca et al., 2021, 2022; De Houwer, 2003; Hasshim & Parris, 2014; 2015) – which permits the independent measurement of *standard* and *semantic* Stroop interference (see Figure 2 and section 2.2). In the Stroop task, distractions can cause conflict at multiple stages within the information-processing stream (see semantic vs. response conflict in Figure 2) – conflict that may be inhibited by different subsystems (Parris et al., 2022; see also e.g., Berggren & Derakshan, 2014 who showed anxiety affected only one subsystem of attentional control).

To sum up, the first goal of the present study was to assess the effect of exposure to nature on inhibition in the Stroop task; the second goal was to investigate whether the effect on inhibition is general or whether it is limited to a particular subsystem of control.

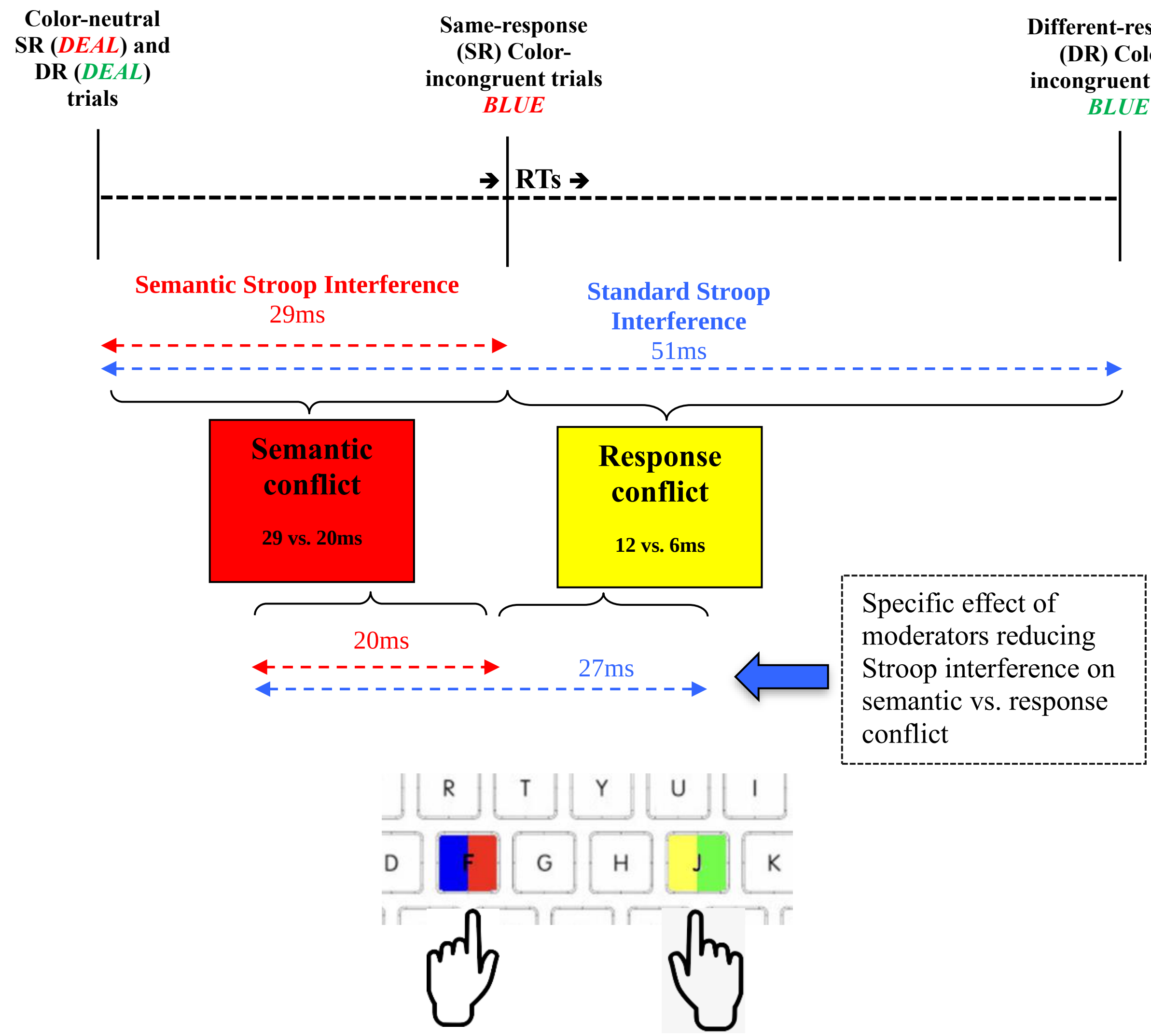

Figure 2. *The two-to-one Stroop paradigm (De Houwer, 2003; Hasshim & Parris, 2014). Its "subtractive" logic (applied here to the data from Burca et al., 2021) makes it possible to differentiate between the respective contributions of semantic versus response conflict to the overall Stroop interference and thus to clearly determine the type of conflict(s) a given intervention (exposure to nature here) influences.*

2. Method

2.1. Participants

One hundred and fifty-four (148 females and 6 males; M_{age}=19.2; *SD*=2.0) undergraduates at Université Clermont Auvergne with normal or corrected-to-normal color-vision took part in this experiment in exchange for a course credit. This study was approved by the local ethics committee (IRB00011540-2021-38).

2.2. Apparatus and Procedure

The study – created with Psychopy 2020.2.10 and ran online with pavlovia.org – was presented as one on color-identification. The participants were instructed to identify the color of the stimulus presented on the screen – as quickly and as accurately as possible – by pushing the appropriate response-button and to ignore everything else in the display. A fixation cross ("+") appeared for 500msec in the center of the screen at the beginning of each trial and remained on screen until the participant responded or until 3000msec had elapsed. After 500msec, the fixation cross ("+") appeared again.

The stimuli were presented in lowercase Courier font, 0.04 height unit size, on a black background. They consisted of four color-words: *rouge* [red], *jaune* [yellow], *bleu* [blue], and *vert* [green]; and four non-color counterparts: *plomb* [lead], *liste* [list], *page* [page], *cave* [basement], that were paired in length and frequency via *Lexique 3.38* (New et al., 2004). The participants first completed 48 practice trials consisting of hashtags in order to learn the color-button correspondence. They proceeded to the experimental block if their accuracy rate was above 75 % (a second practice block was completed if the 75 % accuracy rate was not reached during the first try).

The participants responded manually such that half of the participants used "f" response-key (e.g., actioned with left pointing finger) for responses to blue and red (i.e., target) items, and "j" response-key (e.g., actioned with right pointing finger) for responses to green and yellow items. This color-assignment (that was opposite for the other half of participants) generates two kinds of color-incongruent trials: trials like $BLUE_{\text{red}}$ are termed *same-response trials* because the response activity primed by both the distractor "*BLUE*" and the target color "red" converge toward the same (here 'f'). Consequently, significant interference they produced (compared to their color-neutral counterparts, i.e., semantic Stroop interference) is solely due to *semantic* conflict between the two simultaneously activated color-concepts

(“BLUE” vs. “RED”, see e.g., Seymour, 1977). An additional (i.e., response) conflict occurs for *different-response* incongruent trials (*BLUE*$_{\text{green}}$) because the distractor (“BLUE”) prompts the incorrect (pre)response activity of the left hand toward “f” response-key that interferes with correct response activity of the right hand toward “j” response-key generated by the target (“GREEN”). Thus, significant interference they produced (compared to their color-neutral counterparts, i.e., standard Stroop interference) is due to both semantic and response conflicts (see Figure 2). In sum, the reduction of standard (as opposed to semantic) interference would show that the exposure to nature boosts inhibition of prepotent responses (Augustinova & Ferrand, 2014).

Because of this aforementioned color assignment, together with the fact that color-stimuli only appeared in incongruent colors (i.e., no color-congruent stimuli were included), a single presentation of the full set of color-stimuli in all possible colors resulted in four same-response items (e.g., “blue” in red, “red” in blue, “green” in yellow and “yellow” in green) and eight different-response items (e.g., “blue” in yellow and green, “red” yellow and green, “green” in blue and red and “yellow” in blue and red). To control for contingency (see Introduction), the same presentation was used for the items' color-neutral counterparts (e.g., *DEAL* only appeared in red, yellow and green, exactly like its color-incongruent counterpart *BLUE* as in Burca et al., 2021). Consequently, all conditions of Stimulus-type were seen an equal number of times. This set of 24 different stimuli was repeated 6 times, which resulted in a total of 144 experimental stimuli randomly intermixed in each block [i.e., 24 same-response incongruent trials and 24 color-neutral trials paired with SR-incongruent trials (allowing to compute semantic Stroop interference); 48 different-response incongruent trials, and 48 color-neutral trials paired with DR-incongruent trials (allowing to compute standard Stroop interference)].

In-between the two blocks (each lasting about 6-7min according to the speed of responding), the participants either viewed 25 images of natural environments or 25 control images that consisted of geometric shapes administered by Neilson et al. (2021, based on Berto, 2005). As in Berto (2005), each image was presented for 15sec resulting in total exposure duration of 6min and 25 sec. Directly after this exposure period, a simplified (French) version (back-and-forth translated by the authors) of a shortened version of The Perceived Restorativeness Scale (PRS, Hartig et al., 1996) that was developed by Berto (2005) was given to the participant. Each of the five questions (see Supplemental Materials) referred to pictures that participants had just seen (e.g., "These pictures take me away from everyday demands and where I would be able to relax and think about what interests me." instead of "*That is a place which is* away from (…).)". They responded to these statements on a 9-point scale ranging from complete disagreement (i.e., *-4 not at all agree*) to complete agreement (i.e., *4 = completely agree*) encompassing a neutral 0 point.

2.3. Design, power- and data analysis

The study used a 4 (Stimulus-Type: different response vs. same response vs. neutral different response vs. neutral same response) × 2 (Block: before vs. after exposure) × 2 (Picture-type: natural vs. control) design with latter factor being between-participant. Whilst, for an effect size of 0.25, G*Power (Faul et al., 2009) recommended a total sample size of 120 participants, it was increased to 154 to permit 1600 observations per each condition, necessary for a properly powered experiment with repeated measures (Brysbaert & Stevens, 2018). To achieve this for SR trials (without counting errors), the required number of participants was 67 participants for each group. Given that 74 participants were randomly assigned to the experimental group (natural environment pictures), and 80 participants to the control group (geometric shape pictures), the present experiment can be considered appropriately powered, and this remains true even after the exclusion of one participant in each group due to an error-rate > 50 % in at least one condition of Stimulus-Type. All analyses were therefore performed on the remaining 152 participants (73 in the natural images condition). Bayes factors were employed to assess the sensitivity of our analyses given recent studies showing exposure to pictures of natural environments has no effect on attentional control (Johnson et al., 2021; Neilson et al., 2021; see also Frost et al., 2022).

3. Results

3.1. Efficiency of Experimental induction

Cronbach's alpha was calculated to check the reliability of our modified version of the short PRS. Given that it reached a satisfactory level (.83), mean PRS scores were analyzed as a function of Exposure-type: natural environments vs. control images using an independent t-test. As in past studies, pictures of nature were perceived as significantly more restorative (*M*=5.17; *SD*=1.47) than control pictures (i.e., geometric shapes [*M*=2.68; *SD*=1.57, $t(150)=10.067$; $p=1.560e^{-18}$]). This conclusion was reinforced by a Bayes factor $BF_{10}=2.490e^{+15}$ (evidence for alternative hypothesis compared to null hypothesis calculated with JASP 0.15 default prior parameters) that provided extreme evidence (interpretation according to Lee and Wagenmakers, 2013 adjusted from Jeffreys, 1961) for the alternative compared to the null hypothesis.

3.2. Influence of Exposure to Natural Environments in the Stroop task

Before conducting the omnibus 4 (Stimulus-Type: different response vs. same response vs. neutral different response vs. neutral same response) × 2 (Block: before vs. after exposure) × 2 (Picture-type: natural vs. control) standard frequentist and Bayesian ANOVA, *RT*s 3 *SD*s above and below each participant's mean latency for each condition were excluded from the analysis. This resulted in the exclusion of less than 2% of the total data.

The aforementioned analyses on RTs (see Supplemental Materials for the analysis of errors that mirrored results reported hereafter) revealed a main effect of Stimulus-Type [$F(3,450)=34.523$; $p=4.251e^{-20}$, $\eta_p^2=0.187$; $BF_{10}=3.239e^{+6}$]. Its further decompositions revealed that the present study showed typical Stroop findings (see Figure 2). Indeed, both standard [$t(151)=9.595$; $p=2.560e^{-17}$; $d=0.778$; $BF_{10}=2.153e^{+14}$] and semantic [$t(151)=2.442$; $p=0.016$; $d=0.198$] Stroop interference of 37 msec and 10 msec respectively were significant, although the latter was supported by only an anecdotal $BF_{10}=1.596$ (see Table 1 for descriptive statistics). Therefore, standard (unlike semantic) Stroop interference was likely to involve an additional contribution of response conflict (see Figure 2 and Table 1).

Table 1 *Color-Identification Performance (Means, Standard Error, 95% Credible Intervals and Percent Errors) observed for each Stimulus-Type*

RTs	M (SE)	CI	%ER
Different Response (DR)	608 (9)	[589, 626]	5.19
Same Response (SR)	594 (9)	[577, 611]	3.99
Neutral Different Response (NDR)	571 (7)	[556, 585]	3.53
Neutral Same Response (NSR)	584 (8)	[568, 601]	4.62
Magnitudes (based on RTs)			
Standard Stroop Interference (DR - NDR)	37$^{†/†}$ (4)	[30, 45]	1.65$^{†/†}$
Response Conflict (DR – SR)	14$^{†/**}$ (4)	[6, 21]	1.20$^{†/†}$
Semantic Stroop Interference (SR - NSR)	10$^{*/\circ}$ (4)	[2, 18]	-0.63$^{\circ/\circ}$

Note. Significance of standard inferential: °non-significant, **p* < .05, ***p* < .01, †*p* < .001; and of Bayesian statistics (after forward slash): °$BF_{10} < 3$, *BF_{10} = 3-10, **BF_{10}=10-100], †$BF_{10} > 100$

Performance was modified by Block, as revealed by the significant main effect of Block [$F(1,150)=135.145$; $p=1.120e^{-22}$, $\eta_p^2=0.474$; $BF_{10}=1.379e+81$] revealing that *RT*s in the block preceding the exposure to pictures were significantly longer (*M*=626, *SD*=122, CI=[607,646]) than those observed in the second block (*M*=552, *SD*=91, CI=[537,566]).

The main effect of Picture-type on mean *RT*s remained non-significant [$F(1,150)=1.562$; $p=0.213$, $\eta_p^2=.010$; $BF_{10}=0.451$] and $BF_{01}=2.217$ (evidence for null hypothesis compared to alternative hypothesis calculated with JASP 0.15 default prior parameters). provided at least anecdotal evidence against this effect. Its interaction with both Stimulus-Type [$F(3,450)=0.869$; $p=0.457$, $\eta_p^2=.006$; $BF_{10}=0.009$] and Block [$F(1,150)= 0.054$; $p=0.816$, $\eta_p^2=3.614e^{-4}$; $BF_{10}=0.100$] were also non-significant. Furthermore, $BF_{01}=104.602$ provided extreme evidence against Stimulus-Type × Picture-type interaction and $BF_{01}=9.978$ moderate evidence against Block × Picture-type interaction. The Stimulus-Type × Block interaction was significant [$F(3,450)=6.367$; $p=3.112e^{-4}$, $\eta_p^2=0.041$] in standard frequentist ANOVA. Its further decomposition suggests that significant standard and semantic Stroop interference of 49msec and 17msec respectively were both reduced in the second block such that semantic (unlike standard Stroop interference of 25 msec) was no longer significant (see Table S1 for descriptive statistics). However, $BF_{10}=0.441$ was inconclusive and $BF_{01}=2.267$ actually provided anecdotal evidence against this interaction. In any case, these latter differences in RTs are unlikely to result from exposure to pictures, namely those of nature, since Stimulus-Type × Block × Exposure-type interaction was non-significant [$F(3,450)=1.356$; $p=0.256$, $\eta_p^2=0.009$; $BF_{10}=0.040$] and $BF_{01}=24.850$ provided strong evidence against this interaction (see Table 1S in Supplemental Materials for descriptive statistics).

This conclusion was further reinforced by the analysis of semantic and standard Stroop interference in an additional 2 (Interference-Type) × 2 (Block: before vs. after exposure) × 2 (Picture-type: nature vs. control) ANOVA. This 3-way interaction remain non-significant [$F(1,150)=1.349$; $p=0.247$, $\eta_p^2=0.009$; $BF_{10}=0.338$] and $BF_{01}=2.956$ provided at least anecdotal evidence against this interaction (see Table 2S in Supplemental Materials for descriptive statistics). Also, and importantly, sequential analyses (see Figure 3) showed that adding more participants would not modify this outcome. Indeed, Bayes factor provided moderate evidence

(BF_{01}=5.146) against the effect of Picture-type on standard Stroop interference in the (crucial) block of the Stroop task administered after this exposure. Similarly, BF_{01}=1.313 provided anecdotal evidence against the effect of Picture-type on semantic Stroop interference. The same conclusion was achieved when the sequential analyses were conducted on z-scores (i.e., used to control for changes in the speed of processing reported above). BF_{01}=3.114 provided again moderate evidence against the effect of Picture-type on standard Stroop interference, and BF_{01}=1.536 anecdotal evidence against the effect of Picture-type on semantic Stroop interference.

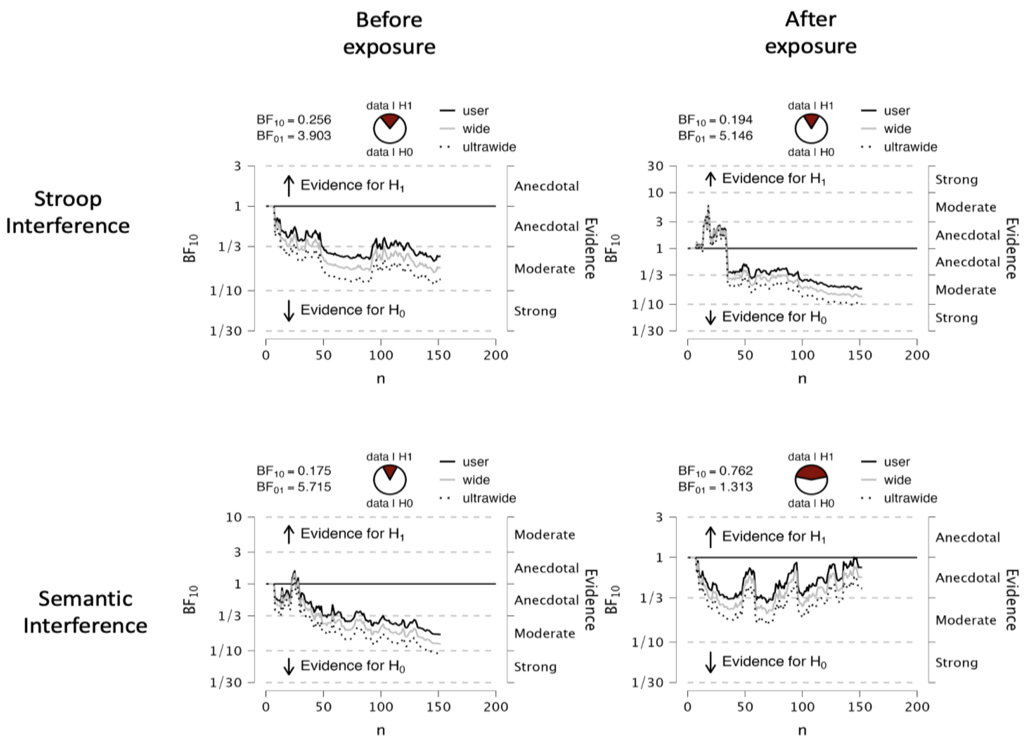

Figure 3. *Sequential analyses for the effect of Picture-type on RTs in 2 (Interference-Type) × 2 (Block: before vs. after exposure) × 2 (Picture-type: nature vs. control) ANOVA.*

4. Discussion and Conclusion

The first goal of the present study was to unambiguously assess the extent to which exposure to nature reduces Stroop *interference* (as opposed to facilitation and/or contingent responding). To this end, these possible confounds (see e.g., Hasshim & Parris, 2014 for discussion) – present in past studies – were eliminated (i.e., congruent trials producing facilitation were not included and response contingency was controlled), and the magnitudes of interference produced by color-incongruent trials before and after exposure to pictures of nature were measured against color-neutral trials. Because *standard* Stroop interference is a composite phenomenon (Zhang & Kornblum, 1998; Zhang et al., 1999; but see e.g., Roelofs, 2003 for a unitary view), the additional measure of *semantic* Stroop interference (i.e., interference that is free of response conflict) was also collected permitting the second goal of the present study which was to examine the level of processing (semantic vs. response) that is affected by attentional restoration that was a priori expected after the exposure to pictures of nature.

In line with past findings showing that repeated execution of the Stroop task reduces interference (e.g., Davidson et al., 2003; Dulaney & Rogers, 1994; Stroop, 1935; Wilkinson & Yang, 2012), RTs observed in the block after the exposure to pictures of nature decreased overall. This increased response speed subsequently reduced standard Stroop interference (Hasshim et al., 2019) and eliminated semantic Stroop interference (Scaltriti et al., 2022), although Bayesian evidence suggest that both types of interference were reduced in tandem. However, despite showing these typical Stroop findings and being appropriately powered, the present study failed to provide any evidence that the aforementioned reduction of Stroop interference resulted from exposure to pictures of nature. Indeed, Bayes factors provided evidence against this effect in both errors, and in reaction times, and this conclusion was reinforced by sequential analyses. Therefore, the present study joins that of Johnson et al. (2021) and Neilson et al. (2021) who both failed to show a benefit of pictures in the sustained attention task (see also Frost et al., 2022 for limited effects of virtual reality on tasks measuring psychological well-being).

Of course, these null-findings in the Stroop task are limited to the effect of pictures. Actual (i.e., physical) immersion into natural environments might still provide an actual boost to attentional control. Therefore, future studies need to examine whether the effect of physical immersion into nature can still be observed in studies that have larger sample sizes. This is even more important since the sequential analyses reported in the present study showed a peak toward moderate evidence in favor of the exposure to pictures around the 20^{th} participant (see Figure 3). If there is indeed a benefit of immersion into nature, it might constitute a useful venue for restoring attentional control, which may be needed in the context of the now increasingly adopted post-pandemic work-from-home policies (Business News Daily, n.d.). In conclusion, the present study suggests that exposing distant workers to pictures of nature – during and after online working – does not seem to be effective for replenishing directed attention (inhibition) as employed in the Stroop task. Such an intervention could therefore be counterproductive for reducing *Zoom exhaustion* (Morris, 2020) as it increases screen time and other risks associated with this ubiquitous sedentary behavior (see e.g., Neophytou et al., 2021).

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