Measuring attention and vigilance in the laboratory vs. online: The split-half reliability of the ANTI-Vea

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Abstract

Over the past few years, there has been growing interest in using online methods for collecting data from large samples. However, only a few studies have administered online behavioral tasks to assess attention outside the lab. In the present study, we assessed the classic attentional functions and two vigilance components using two versions of the Attentional Networks Test for Interactions and Vigilance—executive and arousal vigilance components (ANTI-Vea): (1) a standard version, performed under typical experimental conditions ($n = 314$), and (2) an online version, completed outside the lab ($n = 303$). Both versions were equally effective in assessing (1) the main effects and interactions of phasic alertness, orienting, and executive control, and (2) the executive (i.e., a decline in the ability to detect infrequent critical signals) and the arousal (i.e., a progressive slowness and variability in responses to stimuli from the environment) vigilance decrement across time on task. Responses were generally slower in the online than in the standard version. Importantly, the split-half reliability observed for both tasks was (1) higher for executive control ($\sim .67$) than for phasic alertness and orienting ($< .40$), as observed in previous versions of the task, and (2) between .71 and .99 for the executive and arousal vigilance measures. We expect the present study will be of interest to researchers aiming to assess attentional functions with a valid and reliable method that, importantly, is publicly available on an open website (<https://www.ugr.es/~neurocog/ANTI/>) and is easy to use in applied contexts.

Keywords Attentional Networks Test · Executive vigilance · Arousal vigilance · Reliability · Online assessment

According to a widely acknowledged theory on attention, attentional processes are supported by three independent networks which, nevertheless, may interact with one another (Petersen & Posner, 2012; Posner & Petersen, 1990). In particular, (1) the alerting network underlies both phasic alertness

(i.e., a brief increment in arousal) and vigilance (i.e., sustaining attention for a long time) (Posner, 2008); (2) the posterior network directs attentional orienting towards a potentially relevant source from the environment for stimuli selection (Posner, 2016); and (3) the anterior network modulates executive control processes to adapt our behavior for long-term goals (Shenhav, Botvinick, & Cohen, 2013). To simultaneously assess the different components of the attentional networks, there is considerable interest in developing extended and more sensitive versions of the classic Attentional Networks Test (ANT) (see, e.g., Callejas, Lupiáñez, & Tudela, 2004; Fan, McCandliss, Sommer, Raz, & Posner, 2002; Roca, Castro, López-Ramón, & Lupiáñez, 2011).

In the present study, we examine the feasibility of a recent version of the ANT, the Attentional Networks Test for Interactions and Vigilance—executive and arousal components (ANTI-Vea; Luna, Marino, Roca, & Lupiáñez, 2018), to assess, both in the lab and through an online website, the independence and modulations of the classic attentional functions (i.e., phasic alertness, orienting, and executive control), along with the decrement across time on task of two different components of vigilance: executive vigilance (EV) and arousal

The methods, analysis, and data sets generated and analyzed during the current study are available in the Open Science Framework repository, <https://osf.io/q85bu/>

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vigilance (AV). To further examine whether the ANTI-Vea task can be easily and reliably administered online (Claypoole, Neigel, Fraulini, Hancock, & Szalma, 2018), we also provide new evidence concerning the reliability of the measures obtained both in the typical lab conditions and by online assessment.

The Attentional Networks Test

To assess the independence and efficiency of the three attentional networks in a single session, Fan et al. (2002) developed the ANT, a behavioral task that combines a spatial cueing paradigm (Posner, 1980) and a flanker task (Eriksen & Eriksen, 1974). Callejas et al. (2004) later proposed a modified version of the ANT (i.e., the ANT for Interactions, or ANTI) to further assess both the independence and the interactions between the attentional networks components. In the ANTI, to assess the executive control network, participants have to perform a flanker task by responding only to the direction pointed by the target (i.e., a central arrow) while ignoring the direction pointed by the surrounding flanking arrows. To respectively assess the phasic alertness and the orienting networks, before the appearance of the target and flankers above or below the fixation point, the string of arrows can be (1) anticipated or not by an auditory warning signal, and (2) cued by either a valid spatial cue (i.e., an asterisk appearing at the same location), an invalid spatial cue (i.e., an asterisk appearing at the opposite location), or non-cued by any cue.

Importantly, although the ANT and the ANTI are appropriate for assessing the classic attentional components, these tasks can only provide indirect measures of vigilance, such as the overall reaction time (RT) or the RT difference between the last and the first experimental block (Callejas, Lupiáñez, Funes, & Tudela, 2005; Ishigami & Klein, 2010). To overcome this limitation, Roca et al. (2011) developed the ANT for Interactions and Vigilance (ANTI-V), which indeed assesses vigilance similarly to the classic Sustained Attention to Response Task (SART; Robertson, Manly, Andrade, Baddeley, & Yiend, 1997) or the Continuous Performance Test (CPT; Conners, 2000). Thus, in the ANTI-V, participants perform the ANTI task in most trials (75%), but they have to remain vigilant to detect an infrequent (25% of trials) displacement of the target from its central position.

Interestingly, in previous studies wherein the psychometric properties of the ANT and the ANTI were analyzed, executive control has shown a higher reliability score than phasic alertness and orienting (Fan et al., 2002; Fan, Wu, Fossella, & Posner, 2001; Ishigami & Klein, 2010; MacLeod et al., 2010). This might indicate that executive control represents perhaps an attentional trait, whereas phasic alertness and orienting might rather be related to attentional states

(MacLeod et al., 2010). Note that, importantly, higher reliability scores have nevertheless been observed for the ANTI than for the ANT, especially for phasic alertness and orienting (Ishigami & Klein, 2010). Subsequently, when the reliability of the ANTI-V was examined in a study conducted with a large sample size ($N = 234$), the results from the Spearman–Brown prophecy formula applied to the split-half correlations demonstrated that (1) only executive control still showed higher reliability (.66) than that observed for both phasic alertness and orienting (i.e., below .35), in the same vein as in previous literature with the ANT and the ANTI (Ishigami & Klein, 2010; MacLeod et al., 2010); and (2) critically, all the vigilance indices showed acceptable relative reliability¹ (i.e., between .71 and .93) (Roca, García-Fernández, Castro, & Lupiáñez, 2018).

Measuring vigilance online

In recent years, there has been a notable increase in the administration of online and self-report methods for the collection of large data samples, a trend that has been driven in part by the critical need to improve the replicability of results reported in psychological science (Munafò et al., 2017; Sassenberg & Dittrich, 2019). In particular, online assessment has become a suitable and low-cost alternative for researchers interested in achieving a high number of observations within a short period of time (Germine et al., 2012). Thus, just to give an example, the last major version of PsychoPy (Peirce et al., 2019)—the Python toolbox for developing psychological experiments—was released along with the Pavlovía project (<https://pavlovía.org/>), an open-access website useful for researchers interested in running, sharing, and exploring online experiments.

Nevertheless, it is worth noting that in an online session, the experimental conditions would not be as controlled as in the lab, and this concern might be one of the main reasons that only a few studies have administered vigilance tasks online so far (Fortenbaugh, DeGutis, & Esterman, 2017; Ralph, Thomson, Seli, Carriere, & Smilek, 2015; Sadeh, Dan, & Bar-Haim, 2011; Thomson, Besner, & Smilek, 2016; Vogel et al., 2020). Nevertheless, and importantly, vigilance was successfully measured in the above-cited studies. For instance, whereas Ralph et al. (2015) and Thomson et al. (2016)

¹ Criteria for qualifying the reliability scores seem to differ across studies, in particular depending on the field of research (e.g., applied, clinical, or basic research). For instance, MacLeod et al. (2010) considered the reliability observed in the ANT as low in scores below .40 and moderate–high in a score of .65. However, all these scores are below what typically seems to be considered acceptable reliability (Draheim et al., 2019). Therefore, and for the sake of simplicity, in the present study we consider the criteria selected in a recent review and discussion on this topic by Draheim et al. (2019), which states that reliability scores (1) below .70 are problematic, (2) between .70 and .79 are borderline, and (3) equal to or greater than .80 are acceptable.

observed the vigilance decrement phenomenon (i.e., a progressive decline in sustained attention across time on task) through an online signal detection task, Sadeh et al. (2011) found that an online version of the CPT was sensitive for assessing the effects of sleep deprivation over vigilance performance. Furthermore, the results reported by Thomson et al. (2016) were replicated when the same vigilance task was administered in the typical lab conditions (Claypoole et al., 2018).

The present study

We have recently developed the ANTI-Vea task, a new version of the ANT suitable for assessing the classic attentional functions (as in the ANT) along with two different components of vigilance (Luna et al., 2018). In particular, the EV component is measured as the ability to sustain attention over long periods to detect infrequent critical signals, as in the CPT (Conners, 2000) or the SART (Robertson et al., 1997). Note that, while the ANTI-V was not suitable for observing the decrement in performance across time on task (Roca et al., 2011), with the ANTI-Vea the EV decrement was observed as a progressive increment in the response bias towards a more conservative criterion (Luna et al., 2018), in the same vein as in recent vigilance studies (Claypoole et al., 2018; Thomson et al., 2016). In contrast, the AV component is assessed as in the Psychomotor Vigilance Test (PVT), as the capacity to maintain a fast and automatic reaction to stimuli from the environment without much control over the response executed (Lim & Dinges, 2008). Importantly, the ANTI-Vea is sensitive for observing the AV decrement as a progressive increment in the mean and variability of RT across time on task (Luna et al., 2018), similar to previous findings reported with the PVT (Basner & Dinges, 2011; Lamond et al., 2008).

Taking the above-mentioned issues into account, we conducted the present study with a twofold goal: (1) to examine whether the online version of the ANTI-Vea was also suitable for assessing the independence and interactions of the classic attentional components along with the EV and AV decrement, as observed in typical lab conditions; and (2) to further assess the psychometric properties of both task versions, by analyzing the split-half reliability of the attentional and vigilance measures computed in both the standard ANTI-Vea (i.e., administered in the lab) and the online ANTI-Vea. To do so, we designed a publicly accessible website to run and collect online data with the ANTI-Vea (<https://www.ugr.es/~neurocog/ANTI/>). Thus, the present study seeks to provide novel evidence for researchers interested in administering an easy-to-use online task to assess the classic attentional functions and the vigilance components within a single session.

Method

Participants

Computing split-half reliability indices generally requires a relatively large sample size (MacLeod et al., 2010; Roca et al., 2018). Thus, we collected data from 617 participants (see descriptive statistics in Table 1) with either the standard version ($n = 314$) or the online version ($n = 303$) of the ANTI-Vea task. Participants were at least undergraduate students, and most received extra course credit (0.1/hour). To analyze the performance in the standard ANTI-Vea, we combined data from healthy participants who were included in previous non-clinical studies with the ANTI-Vea (Luna, Barttfeld, Martín-Arévalo, & Lupiáñez, *in press*; Luna et al., 2018; Luna, Martín-Arévalo, Foa Torres, & Lupiáñez, 2020b; Pirruccio, 2018; Puente-Ontanilla, 2018). Then, we collected data from a similar sized group with the online ANTI-Vea. The study was conducted according to the ethical standards of the 1964 Declaration of Helsinki (last update Seoul, 2008), and was part of a larger research project that has been positively evaluated by the University of Granada Ethical Committee (536/CEIH/2018).

Apparatus and stimuli

Following Luna et al. (2018), the standard ANTI-Vea was designed and run in E-Prime 2.0 Professional (Psychology Software Tools, I, 2012). We used JavaScript ES5, HTML5, CSS3, and Angular JS to design and run the online ANTI-Vea. Stimuli and instructions were the same for both versions. They were presented over a gray background and within a screen resolution 1024 pixels (px) wide $\times$ 768 px high, with participants sitting at a distance of ~ 50 cm from the screen when completing the standard task. The stimuli set comprised a black cross (~ 7 px) as the fixation point, a black asterisk (~ 13 px) as the visual cue, a tone (2000 Hz) as the warning signal, five black arrows in a row pointing either leftward or rightward (50 px wide $\times$ 23 px high each arrow, separated by ~ 63 px) as the target and flankers, and a red millisecond countdown timer (~ 110 px height each number) as the AV stimuli. Responses were collected on a standard keyboard.

Procedure and design

Participants who performed the standard ANTI-Vea completed the session under typical lab conditions. They performed the task individually in an experimental room, using headphones to hear the warning signal. In contrast, the participants that performed the online ANTI-Vea completed the task at home or in a suitable place of their choosing where they could access the website on a computer. We included additional instructions to reduce any possible distractions during

Table 1 Descriptive statistics of participants who performed the standard or the online version of the ANTI-Vea task. For mean age, the standard deviation is shown in parentheses

	<i>n</i>	Sex		Age	Location
		Women	Men		
Standard					
Experiment 1 ^a	40	20	20	25.48 (6.60)	Córdoba (Argentina)
Experiment 2 ^b	42	30	12	22.50 (5.18)	Córdoba (Argentina)
Experiment 3 ^c	80	70	10	19.11 (2.16)	Granada (Spain)
Experiment 4 ^d	41	34	7	20.10 (3.17)	Granada (Spain)
Experiment 5 ^e	49	18	31	31.06 (4.07)	Madrid (Spain)
Experiment 6 ^f	62	35	27	25.44 (4.87)	Córdoba (Argentina)
Overall	314	207	107	23.62 (5.94)	
Online					
Subgroup A	150	111	39	23.27 (4.53)	Córdoba (Argentina)
Subgroup B	84	73	11	19.71 (3.53)	Granada (Spain)
Subgroup C	40	33	7	20.60 (2.28)	Valencia (Spain)
Subgroup D	16	12	4	22.63 (1.15)	Padova (Italy)
Subgroup E	13	9	4	23.46 (5.19)	Not informed
Overall	303	238	65	21.91 (4.24)	

Note. ^a Experiment 2 of Luna et al. (2018), ^b Luna et al. (in press), ^c Experiment 3 of Pirruccio (2018), ^d Experiment 4 of Pirruccio (2018), ^e Puente-Ontanilla (2018), ^f Luna, Martín-Arévalo, et al. (2020b)

performance of the task online. These additional instructions were presented before the standard instructions and warned the participants that the task would be displayed on the full screen, and that it was important to perform the entire task without interruption, trying as much as possible to avoid any distractions. In addition, they were asked to set the sound level of the computer at 75%, to turn their mobile phone on mute, and to turn off the vibration function, trying to keep it out of their reach while performing the task. Moreover, they were asked to turn off any entertainment device (e.g., television or radio). Lastly, if it was necessary to get up from their seat for any particular reason, it was suggested that they do so before starting the task. Then, to familiarize participants with the three types of trials of the ANTI-Vea (i.e., ANTI, EV, and AV trials), both groups received specific instructions and completed several practice blocks with visual feedback, as in Luna et al. (2018).

The ANTI-Vea comprises three different types of trials, which are randomly presented within the experimental blocks: (1) the ANTI (60%), which are suitable for assessing the main effects and interactions of the classic attentional functions; (2) the EV (20%), in which participants perform a signal-detection task similar to the SART (Robertson et al., 1997) or the CPT (Conners, 2000); and (3) the AV (20%), which are similar to the PVT (Lim & Dinges, 2008). In particular, the ANTI trials followed the procedure of the ANTI task (Callejas et al., 2004). Participants had to perform a flanker task, responding to the direction pointed by a central arrow (i.e., the target) while ignoring the direction pointed by two

distracting arrows at each side. Stimuli could randomly appear above or below the fixation point. To assess the executive control network, in half of these trials the target and the distractors pointed in the same direction as the target (congruent condition), whereas in the other half the distractors pointed in the opposite direction of the target (incongruent condition). In addition, to assess phasic alertness, in half of these trials a warning signal anticipated the response stimuli (tone condition), whereas in the other half there was no warning signal (no tone condition). Lastly, to assess the orienting network, a visual cue was presented above/below the fixation point either (1) at the same location as the string of arrows (valid condition, one-third of trials) or (2) at the opposite location (invalid condition, one-third of trials), or (3) was not presented at all (no cue condition, one-third of trials). The stimuli sequence and timing, correct responses, and examples of congruency and visual cue for the ANTI trials are depicted in Fig. 1.

The EV trials followed the same procedure as the ANTI trials, with the single difference that the target appeared quite displaced (8 px) from its central position, either upwards or downwards (see Fig. 1). To correctly perform the EV trials, participants were instructed to remain vigilant at all times while attempting to detect the displaced targets. Importantly, to make the detection of the displaced targets more difficult, arrows were not presented at exact positions; instead, the vertical and horizontal positions of each arrow had a random variability of ± 2 px, both in the ANTI (for target and flankers) and EV (only for flankers) trials. Therefore, in the ANTI trials, the maximum vertical distance between the target and one of

the two adjacent flankers was 4 px and the minimum was 0 px, whereas in the EV trials it was between 10 px and 6 px, respectively. Lastly, the AV trials had the same timing as the ANTI and EV ones but did not include any warning signal, visual cue, or arrow stimuli (see Fig. 1). The AV trials were similar to the PVT (Lim & Dinges, 2008): the fixation point remained on the screen until a red millisecond countdown timer appeared, and participants were instructed to stay vigilant and to stop the counter as quickly as possible by pressing any key on the keyboard (see Fig. 1).

Participants completed six experimental blocks, with no pause or visual feedback, with 80 randomized trials per block (48 ANTI, 16 EV, and 16 AV). The 48 ANTI trials per block were selected from the following factorial design: Warning signal (no tone/tone) $\times$ Visual cue (invalid/no cue/valid) $\times$ Congruency (congruent/incongruent) $\times$ Target direction (left/right) $\times$ Stimuli position regarding the fixation point (up/down). Importantly, the last two factors were not considered for statistical analyses and were only included for stimuli

presentation. In the EV trials, one factor was added to the ANTI trials design: target displacement direction (upwards/downwards). The 16 EV trials per block were randomly selected, without any control, from the 96 total possible combinations of the EV trials.

Statistical analyses

We performed standard analysis of the ANTI-Vea following Luna et al. (in press). Twenty-six participants (4.21%) were excluded from further analyses, as follows: 10 from the standard group and 14 from the online condition due to extreme overall RT or percentage of errors in the ANTI trials (2.5 SD above the group mean), and two participants from the standard group due to a technical issue during data acquisition. We then conducted separate analyses of the attentional networks components, the vigilance components, the correlational analyses between the attentional and vigilance components, and the split-half reliability analysis. Attentional and vigilance

Fig. 1 Procedure of the ANTI-Vea task. **(a)** Stimuli sequence and timing for the ANTI and EV trials. **(b)** Stimuli sequence and timing for the AV trials. **(c)** Examples of visual cue conditions. **(d)** The correct responses expected for the ANTI (see examples of congruency condition), EV, and

AV trials. In all the trials, the first and the last screen had a random timing to set the total trial duration as 4100 ms, and responses were allowed for 2000 ms from the appearance of the response stimuli

performance were analyzed in Statistica 8.0 (StatSoft, 2007). Then, the independence of the attentional and the vigilance scores was analyzed by both Pearson and Bayesian correlations conducted with JASP (2019). Finally, split-half reliability indices of attentional and vigilance components were computed using the *plyr* (Wickham, 2011) and *Hmisc* (Harrell, 2018) libraries in R Studio (R Core Team, 2018). Figures were created with Matplotlib 3.0.0 (Hunter, 2007).

Attentional and vigilance performance

Separate mixed analysis of variance (ANOVA) tests were conducted to analyze attentional and vigilance performance as a function of the task version. In these analyses, the *p* value is reported for null-hypothesis significance testing along with partial eta-squared (η_p^2) as a measure of the effect size. For better comprehension of the size of the effects reported (Cumming, 2014), 95% confidence intervals around effect sizes are provided (Kelley & Preacher, 2012) and η_p^2 values equal to or less than .01 are considered small effects (Cohen, 1988; Fritz, Morris, & Richler, 2012).

In particular, for the ANTI trials, RT analyses excluded trials with incorrect responses (standard = 6.22%; online = 5.91%) and those with RT below 200 ms or above 1500 ms (standard = 0.51%; online = 0.53%). The analysis of the main effects and interactions of attentional components thus included two mixed ANOVAs, one with RT and the other with percentage of errors as dependent variables, and with warning signal (no tone/tone), visual cue (invalid/no cue/valid), and congruency (congruent/incongruent) as within-participant factors and task version (standard/online) as a between-participants factor.

To analyze the EV and AV decrement across time on task, vigilance measures were computed per block of trials. For the EV trials, warning signal, visual cue, and congruency levels were not considered for analyses, with data being collapsed across these variables. First, we computed the rate of hits (i.e., correct responses in the EV trials) and false alarms (FA; i.e., space bar responses in the ANTI trials). Importantly, to avoid the possibility that a floor effect in the FA could mask a considerable shift in the response bias (Thomson et al., 2016), FA were computed following the method developed by Luna et al. (in press). In particular, we categorized offline the ANTI trials as a function of the vertical distance between the position of the target and the closest adjacent flanker, to select only those trials where there was a higher chance of committing a FA. Therefore, the FA rate was computed only considering the trials in which this distance was between 3 and 4 px, excluding the trials where this distance was between 0 and 2 px. Indeed, in those trials where the maximum vertical distance between the target and the closest adjacent distractors was between 0 and 2 px, the FA rate was observed at floor

levels ($M = 1.96\%$, 95% CI [1.71, 2.21] in the standard and $M = 2.36\%$, [2.08, 2.64] in the online task).

Next, nonparametric indexes of sensitivity (A') and response bias (B'') were obtained (Grier, 1971). The advantages of using nonparametric over classic parametric indexes (d' for sensitivity and β for response bias) to analyze the EV decrement in the ANTI-Vea task are discussed in Luna et al. (2018) and can be reviewed in detail in several studies (Stanislaw & Todorov, 1999; Thomson et al., 2016). Additionally, we obtained the mean and SD of RT on hits per block, excluding trials with a RT below 200 ms and above 1500 ms (standard = 0.77%; online = 0.71%). Then, six mixed ANOVAs were conducted separately, one for each dependent variable (hits, FA, A' and B'' , mean RT, and SD of RT), including block (6 levels) as within-participant factor and task version (standard/online) as a between-participants factor.

For the AV trials, we computed the mean RT, SD of RT, and the percentage of lapses (i.e., responses slower than 600 ms), following the criterion established in Luna et al. (2018). Three mixed ANOVAs were then conducted separately, one for each dependent variable (mean RT, SD of RT, and percentage of lapses), including block (6 levels) as a within-participant factor and task version (standard/online) as a between-participants factor.

Correlations between attentional and vigilance components

The analysis of bivariate correlations included the overall RT and the percentage of errors in ANTI trials, and the overall EV and AV measures described above. In addition, we computed the attentional networks scores proposed by Callejas et al. (2004), by subtracting average data in specific conditions: (1) the phasic alertness score as the result of no tone minus tone conditions, considering only trials with no visual cue; (2) the orienting score as the result of invalid minus valid conditions; and (3) the executive control score as the result of incongruent minus congruent conditions.

Importantly, correlations between attentional and vigilance scores were analyzed using two statistical approaches. On the one hand, Pearson correlations were conducted for null-hypothesis significance testing with a *p* level < .05 to reject the null hypothesis (H_0 ; i.e., the absence of correlation between performance scores). Note that, traditionally, the size of Pearson's *r* correlation coefficient has been interpreted following the criteria proposed by Cohen (1988). Nonetheless, this criteria has been observed in some posterior studies (Gignac & Szodorai, 2016; Hemphill, 2003). Then, for the sake of clarity, in the present study we followed the guidelines proposed in the meta-analysis conducted by Gignac & Szodorai (2016) to interpret Pearson's *r* coefficient (1) between .10 and .19 as small, (2) between .20 and .29 as medium, and (3) equal to or greater than .30 as large effects.

Table 2 Description of the computation and theoretical interpretation of each dependent measure obtained with the ANTI-Vea task

Dependent measure	Computation	Theoretical interpretation
Attentional scores ^a		
Overall	Mean across all ANTI conditions	General responsiveness of the attentional networks system
Phasic alertness	No tone minus tone condition (only in no cue trials)	Capacity to briefly increase the alertness state by warning signals from the environment
Orienting	Invalid minus valid condition	Capacity to direct attentional orienting by exogenous visual cues from the environment
Executive control	Incongruent minus congruent condition	Ability to select relevant stimuli among irrelevant ones in conflict situations
Executive vigilance		
Mean RT (ms)	Mean RT on hits	Mean speed on correct detection of infrequent critical signals
SD of RT (ms)	SD of RT on hits	Variability in speed on correct detection of infrequent critical signals
Hits (%)	Correct responses on EV trials	Correct detection of infrequent critical signals
False alarms (%)	Space bar responses on ANTI trials with a distance of 3 or 4 pixels between the target and one of the adjacent distractors	Incorrect attempts to detect the infrequent critical signals
Sensitivity (A') ^b	$\frac{1}{2} + (H - FA) \frac{(1 + H - FA)}{4H(1 - FA)}$	Ability to discriminate infrequent critical signals from non-signal events
Response bias (B'') ^b	$H(1 - H) \frac{-FA(1 - FA)}{H(1 - H)} + FA(1 - FA)$	Criterion to categorize stimuli as an infrequent critical signal
Arousal vigilance		
Mean RT (ms)	Mean RT on AV trials	Mean speed to react to stimuli from the environment without much control
SD of RT (ms)	SD of RT on AV trials	Variability in response speed. Higher variability indicates an out-of-the-zone state, i.e., reduced AV
Lapses (%)	No responses or very slow responses (i.e., equal to or greater than 600 ms) on AV trials	Extremely slow responses to react automatically to stimuli from the environment

Note. ANTI = Attentional Networks Test for Interactions; RT = reaction time; ms = milliseconds; EV = executive vigilance; H = hits; FA = false alarms; AV = arousal vigilance

^a Attentional scores can be computed either with RT on correct trials or with the percentage of errors as dependent variable

^b The formulas for computing nonparametric indices of A' and B'' are correct if the percentage of hits is $\geq$ FA; if not, formulas should be corrected by reversing hits and FA within the formula (see Grier, 1971; Stanislaw & Todorov, 1999)

On the other hand, we conducted Bayesian correlations to test the strength of the evidence supporting either the H_0 or the alternative hypothesis (H_1 ; the existence of a positive or negative correlation among performance scores) (Wagenmakers et al., 2018). For the sake of clarity, and following Jarosz & Wiley (2014), the inverse Bayes factor (BF_{10}) can be interpreted as follows: (1) below 0.33, as consistent evidence in favor for the H_0 ; (2) between 0.33 and 1, as inconsistent evidence supporting neither the H_0 nor the H_1 ; (3) between 1 and 3, as anecdotal evidence for the H_1 ; and (4) above 3, as consistent evidence supporting the H_1 , in particular: between 3 and 10 as substantial, between 10 and 30 as strong, between 30 and 100 as very strong, and higher than 100 as decisive evidence for the H_1 .

Split-half reliability

Following the analyses conducted by Roca et al. (2018) with the ANTI-V task, first, all the experimental trials of each participant were randomly split into two halves, as a function of

(1) the ANTI trial condition (i.e., warning signal, visual cue, or congruency) to compute the attentional networks scores, and (2) the type of trial (ANTI, EV, and AV) to compute ANTI overall RT and percentage of errors, and the EV and AV measures. This procedure was repeated by a permutation approach until we obtained 10,000 pairs of trial halves. Then, for each permutation, we computed the different attentional or vigilance scores in each of the two halves. After that, Pearson correlations across participants were performed between the two halves. The split-half reliability indices were obtained as the average of the 10,000 correlations for each attentional network or vigilance measure. Finally, we applied the Spearman–Brown prophecy formula to extrapolate the test–retest reliability from the split-half reliability (MacLeod et al., 2010). The size of reliability indices was interpreted following Draheim et al. (2019): below .70 as problematic, between .70 and .79 as borderline, and above .80 as acceptable.

For the sake of clarity, a concise description of the computation and theoretical interpretation of each dependent

measure analyzed in the ANTI-Vea task is presented in Table 2 for all the above-mentioned statistical analyses.

Results

Phasic alertness, orienting, and executive control

The typical main effects of the classic attentional functions commonly reported with the ANTI (Callejas et al., 2004) and the ANTI-Vea (Luna et al., 2018) tasks were observed as statistically significant here (see Fig. 2). Thus, for the warning signal effect—RT [$F(1, 589) = 601.16, p < .001, \eta_p^2 = .51, 95\% \text{ CI } (.45, .55)$] and errors [$F(1, 589) = 160.53, p < .001, \eta_p^2 = .21, (.16, .27)$ —responses were faster and more accurate in the tone than in the no tone condition. The visual cueing effect—RT [$F(2, 1178) = 877.16, p < .001, \eta_p^2 = .60, (.57, .63)$] and errors [$F(2, 1178) = 25.90, p < .001, \eta_p^2 = .04, (.02, .07)$ —showed different effects for RT and the percentage of errors. As can be observed in Fig. 2, while responses were faster in the valid condition than in the no cue and invalid ones [$F(1, 589) = 1340.86, p < .001, \eta_p^2 = .69, (.66, .73)$], in the analysis of errors, responses were more accurate in the no cue than in the valid and invalid conditions [$F(1, 589) = 56.31, p < .001, \eta_p^2 = .09, (.05, .13)$]. Lastly, the congruency effect—RT [$F(1, 589) = 1104.86, p < .001, \eta_p^2 = .65, (.61, .69)$] and errors [$F(1, 589) = 9.64, p = .002, \eta_p^2 = .02, (.00,$

.04)]—demonstrated that responses were faster and more accurate in the congruent than in the incongruent condition.

Regarding the differences between the standard and the online ANTI-Vea, there was a significant main effect of task version in RT [$F(1, 589) = 12.14, p < .001, \eta_p^2 = .02, (.00, .05)$], which was not observed in errors ($F < 1$). Thus, in general, responses were faster in the standard than in the online ANTI-Vea (see Table 3 below). Importantly, the warning signal effect (i.e., no tone minus tone condition) was significantly modulated by the task version only for RT [$F(1, 589) = 23.59, p < .001, \eta_p^2 = .04, (.01, .07)$], not for errors [$F(1, 589) = 2.97, p = .086, \eta_p^2 < .01, (.00, .02)$]. As can be seen in Fig. 2, the warning signal effect was smaller in the online than in the standard ANTI-Vea, although clearly significant for both the standard [$F(1, 301) = 432.56, p < .001, \eta_p^2 = .59, (.52, .64)$] and the online [$F(1, 288) = 193.14, p < .001, \eta_p^2 = .40, (.32, .47)$] task. In addition, there was a significant but small modulation of task version over the visual cue—RT [$F(2, 1178) = 4.32, p = .014, \eta_p^2 < .01, (.00, .02)$] and errors [$F(2, 1178) = 5.43, p = .004, \eta_p^2 < .01, (.00, .02)$ —which demonstrated a slightly larger cueing effect (i.e., invalid minus valid conditions) for the RT in the online version than in the standard one (see Fig. 2 and Table 3). Lastly, the interaction between Task version $\times$ Congruency was far from statistical significance (both for RT and errors: $F_s < 1$). Thus, in summary, as can be observed in Fig. 2, significant and similar indices were observed for the two task versions,

Fig. 2 Mean correct RT (top graphs) and percentage of errors (bottom graphs) for the warning signal (left), visual cue (center), and congruency (right) conditions, as a function of the task version (standard/online). Error bars represent 95% CI of the mean

although they were perhaps slightly smaller for the phasic alertness and the cueing effect in the online ANTI-Vea.

In addition, the typical modulations between the classic attentional functions usually reported with the ANTI (Callejas et al., 2004) and ANTI-Vea (Luna et al., 2018) tasks were also observed as statistically significant here (see Fig. 3). The interaction between warning signal and congruency (see Fig. 3) revealed that, whereas the congruency effect (i.e., incongruent minus congruent trials) was increased by the tone condition with RT [$F(1, 589) = 50.76, p < .001, \eta_p^2 = .08, (.04, .12)$], a very small congruency effect was observed with errors, which was slightly reduced by the tone condition [$F(1, 589) = 6.20, p = .013, \eta_p^2 = .01, (.00, .03)$]. The Visual cue $\times$ Congruency interaction (see Fig. 3)—RT [$F(2, 1178) = 41.90, p < .001, \eta_p^2 = .07, (.04, .09)$] and errors [$F(2, 1178) = 5.47, p = .004, \eta_p^2 < .01, (.00, .02)$ —showed that the largest congruency effect was found in the invalid condition, for both RT and errors. Moreover, whereas for the RT the congruency effect was very similar for the no cue and valid conditions, in the analysis of errors, the congruency effect was quite reduced in the valid condition in contrast to the no cue one. The Warning signal $\times$ Visual cue interaction (see Fig. 3) was significantly observed only for RT [$F(2, 1178) = 122.57, p < .001, \eta_p^2 = .17, (.13, .21)$] and not for errors [$F(2, 1178) = 1.56, p = .212, \eta_p^2 < .01, (.00, .01)$], showing that the cueing effect was larger in the tone than in the no tone condition. Lastly, a small three-way interaction was significantly

observed in the analysis of errors [$F(2, 1178) = 3.48, p = .031, \eta_p^2 < .01, (.00, .02)$] but not for RT ($F < 1$).

Furthermore, there was a significant but small modulation of the task version over the interaction between Warning signal $\times$ Visual cue (see also Fig. 3), which was observed only for RT [$F(2, 1178) = 6.14, p = .002, \eta_p^2 = .01, (.00, .02)$] but not for errors [$F(2, 1178) = 2.01, p = .134, \eta_p^2 < .01, (.00, .01)$]. The remaining interactions between the classic attentional components were not modulated by the task version (see Fig. 3): Warning signal $\times$ Congruency—RT ($F < 1$) and errors [$F(1, 589) = 1.29, p = .257, \eta_p^2 < .01, (.00, .02)$]; Visual cue $\times$ Congruency—RT [$F(2, 1178) = 1.56, p = .209, \eta_p^2 < .01, (.00, .01)$] and errors [$F(2, 1178) = 1.72, p = .179, \eta_p^2 < .01, (.00, .01)$]. Finally, as can be observed in Table 3, task version did not modulate the interaction between Warning signal $\times$ Visual cue $\times$ Congruency—RT [$F(2, 1178) = 2.97, p = .052, \eta_p^2 < .01, (.00, .02)$] and errors ($F < 1$).

Executive vigilance decrement

The mean RT [$F(5, 2920) = 5.05, p < .001, \eta_p^2 < .01, (.00, .01)$] and the SD of RT [$F(5, 2895) = 4.61, p < .001, \eta_p^2 < .01, (.00, .01)$] showed a significant but small increment across blocks, with a significant linear trend for both mean [$F(1, 584) = 12.62, p < .001, \eta_p^2 = .02, (.00, .05)$] and SD of RT [$F(1, 579) = 18.11, p < .001, \eta_p^2 = .03, (.00, .06)$].

Table 3 Mean correct RT and percentage of errors for warning signal, visual cue, and congruency conditions, as a function of the task version (standard/online)

		Standard				Online			
		Congruent		Incongruent		Congruent		Incongruent	
		<i>M</i>	95% CI	<i>M</i>	95% CI	<i>M</i>	95% CI	<i>M</i>	95% CI
Reaction time (ms)									
No tone	Invalid	644	[632, 656]	691	[679, 703]	671	[659, 683]	719	[707, 732]
	No cue	647	[635, 659]	681	[669, 694]	670	[658, 682]	705	[693, 717]
	Valid	617	[605, 629]	652	[639, 664]	637	[625, 650]	671	[658, 683]
Tone	Invalid	624	[612, 636]	686	[674, 698]	658	[646, 670]	714	[702, 726]
	No cue	593	[581, 605]	641	[629, 653]	634	[622, 646]	678	[666, 690]
	Valid	584	[573, 595]	623	[612, 635]	611	[599, 622]	658	[646, 670]
Errors (%)									
No tone	Invalid	6.76	[5.97, 7.55]	7.88	[6.96, 8.79]	6.17	[5.36, 6.98]	8.04	[7.11, 8.98]
	No cue	6.62	[5.89, 7.36]	7.00	[6.20, 7.79]	5.84	[5.09, 6.59]	6.36	[5.54, 7.18]
	Valid	7.28	[6.51, 8.06]	7.77	[6.91, 8.63]	6.43	[5.64, 7.22]	7.09	[6.21, 7.97]
Tone	Invalid	5.33	[4.64, 6.01]	5.55	[4.77, 6.32]	5.48	[4.78, 6.18]	6.38	[5.58, 7.17]
	No cue	3.92	[3.33, 4.51]	4.80	[4.09, 5.51]	4.25	[3.65, 4.86]	4.80	[4.07, 5.53]
	Valid	5.92	[5.18, 6.65]	5.88	[5.14, 6.61]	5.39	[4.64, 6.14]	4.57	[3.82, 5.32]

Note. *M* = mean; CI = confidence interval

Fig. 3 Modulations between the classic attentional components as a function of the task version (standard/online). The top graphs show RT as dependent variable, whereas the bottom graphs show the percentage of errors as dependent variable. The interference effect (i.e., the score computed for executive control) is presented as a function of warning

signal (left graphs) and visual cue (center graphs) conditions. The cueing effect (i.e., the score computed for orienting) is presented as a function of warning signal conditions (right graphs). Error bars represent 95% CI of the mean

Interestingly, similarly to mean RT in the ANTI trials, here a significant main effect of task version was observed for both mean [$F(1, 584) = 6.80, p = .009, \eta_p^2 = .01, (.00, .03)$] and SD of RT [$F(1, 579) = 8.75, p = .003, \eta_p^2 = .01, (.00, .04)$]. In general, responses were slightly faster in the standard than in the online task, but in contrast, higher RT variability was found in the standard than in the online version (see Table 4 below). Importantly, the task version did not modulate the increment across blocks for either mean or SD of RT (both $F_s < 1$).

Regarding the analysis of signal detection theory (SDT) metrics, the EV decrement across time on task was observed in the same vein as previous findings reported with the ANTI-Vea task (Luna et al., 2018). Thus, as shown in Fig. 4, we found a significant decrement across blocks of both hits [$F(5, 2945) = 52.47, p < .001, \eta_p^2 = .08, (.06, .10)$], linear trend [$F(1, 589) = 155.48, p < .001, \eta_p^2 = .21, (.15, .26)$], and FA [$F(5, 2945) = 14.00, p < .001, \eta_p^2 = .02, (.01, .03)$], linear trend [$F(1, 589) = 54.53, p < .001, \eta_p^2 = .08, (.05, .13)$]. In addition, there was a significant decrement across blocks of A' [$F(5, 2945) = 13.21, p < .001, \eta_p^2 = .02, (.01, .03)$], linear trend [$F(1, 589) = 39.85, p < .001, \eta_p^2 = .06, (.03, .10)$], and a significant increment across blocks of B'' [$F(5, 2945) = 26.20, p < .001, \eta_p^2 = .04, (.03, .06)$], linear trend [$F(1, 589) = 87.74, p < .001, \eta_p^2 = .13, (.08, .18)$].

Note that, as observed in Fig. 4, a significant although small main effect of task version was observed for both hits

[$F(1, 589) = 4.85, p = .028, \eta_p^2 < .01, (.00, .03)$] and A' [$F(1, 589) = 5.16, p = .023, \eta_p^2 < .01, (.00, .03)$], but not for FA and B'' (both $F_s < 1$). Although it was unexpected, hits and A' were slightly higher in the online than in the standard version (see Table 4 below).

In addition, a small modulation of task version over the decrement in hits [$F(5, 2945) = 2.47, p = .030, \eta_p^2 < .01, (.00, .01)$] and A' [$F(5, 2945) = 3.10, p = .009, \eta_p^2 < .01, (.00, .01)$] across blocks was found. However, the analysis of the linear component showed that task version did not modulate the linear decrement in either hits or A' across blocks (both $F_s < 1$). Thus, it seems probable that the interactions observed between task version and hits/A' are mainly due to data in the third block, as shown in Fig. 4. Finally, task version did not modulate FA ($F < 1$) or B'' [$F(5, 2945) = 1.08, p = .371, \eta_p^2 < .01, (.00, .01)$], thus proving a quite similar EV decrement between the standard and online versions of the ANTI-Vea.

Arousal vigilance decrement

Similar to the EV decrement, an AV decrement across time on task (see Fig. 5) was found, as previously reported with the ANTI-Vea task (Luna et al., 2018). A significant increment across blocks was observed for mean RT [$F(5, 2945) = 15.08, p < .001, \eta_p^2 = .02, (.01, .04)$], SD of RT [$F(5, 2945) = 26.73,$

Table 4 Mean and 95% CI for the attentional networks and vigilance scores as a function of the task version (standard/online)

	Standard		Online	
	<i>M</i>	95% CI	<i>M</i>	95% CI
Attentional scores (RT)				
Overall	640	[629, 651]	669	[657, 680]
Phasic alertness	47	[44, 51]	32	[27, 36]
Orienting	42	[39, 46]	46	[43, 49]
Executive control	44	[41, 48]	44	[40, 47]
Attentional scores (errors)				
Overall	6.22	[5.68, 6.77]	5.90	[5.42, 6.38]
Phasic alertness	2.45	[1.88, 3.02]	1.57	[1.02, 2.12]
Orienting	−0.33	[−0.74, 0.07]	0.65	[0.18, 1.11]
Executive control	0.51	[−0.03, 1.04]	0.61	[0.16, 1.07]
Executive vigilance				
Mean RT (ms)	744	[735, 752]	762	[752, 773]
SD of RT (ms)	134	[130, 138]	126	[122, 130]
Hits (%)	74.9	[72.98, 76.83]	77.77	[76.09, 79.44]
False alarms (%)	6.78	[6.11, 7.45]	6.91	[6.20, 7.62]
Sensitivity (<i>A'</i>)	.912	[.907, .917]	.920	[.915, .924]
Response bias (<i>B''</i>)	.420	[.369, .471]	.412	[.362, .462]
Arousal vigilance				
Mean RT (ms)	487	[480, 494]	523	[511, 535]
SD of RT (ms)	88	[84, 93]	87	[83, 91]
Lapses (%)	10.76	[9.14, 12.38]	15.87	[13.51, 18.23]

Note. *M* = mean; CI = confidence interval; RT = reaction time; SD = standard deviation; ms = milliseconds

$p < .001$, $\eta_p^2 = .04$, (.03, .06)] and the percentage of lapses [$F(5, 2945) = 39.29$, $p < .001$, $\eta_p^2 = .06$, (.05, .08)]. Importantly, the three dependent variables showed a clear linear trend: mean RT

[$F(1, 589) = 35.51$, $p < .001$, $\eta_p^2 = .06$, (.03, .10)], SD of RT [$F(1, 589) = 76.40$, $p < .001$, $\eta_p^2 = .11$, (.07, .16)], and the percentage of lapses [$F(1, 589) = 93.87$, $p < .001$, $\eta_p^2 = .14$, (.09, .19)].

The main effect of task version was clearly observed as significant for mean RT [$F(1, 589) = 25.80$, $p < .001$, $\eta_p^2 = .04$, (.02, .08)] and the percentage of lapses [$F(1, 589) = 12.54$, $p < .001$, $\eta_p^2 = .02$, (.00, .05)], but not for SD of RT [$F(1, 589) = 1.48$, $p = .225$, $\eta_p^2 < .01$, (.00, .02)]. As observed in Fig. 5, and in the same vein as the mean RT computed in the ANTI trials and the EV component, a similar pattern of data was observed with the two tasks in the AV component: responses were faster and there were fewer lapses in the standard than in the online ANTI-Vea (see also Table 4 below).

Finally, task version showed a small modulation over the change in SD of RT across blocks [$F(5, 2945) = 2.26$, $p = .046$, $\eta_p^2 < .01$, (.00, .01)], which was not observed for either mean RT or lapses (both F s < 1). Nevertheless, and most importantly, the analysis of the linear component confirmed that the increment in the SD of RT across blocks did not differ between tasks [$F(1, 589) = 2.52$, $p = .113$, $\eta_p^2 < .01$, (.00, .02)].

Correlations between attentional networks and vigilance components

The overall means of the scores computed to analyze bivariate correlations between attentional and vigilance components are shown in Table 4. For the sake of clarity, the correlations between the classic attentional functions and vigilance components are presented in separate tables.

Fig. 4 Executive vigilance decrement as a function of the task version (standard/online). Graphs show the percentage of hits (top left) and FA (top right), and the indices of sensitivity (bottom left) and response bias (bottom right) per block of trials. Error bars represent 95% CI of the mean

Fig. 5 Arousal vigilance decrement as a function of the task version (standard/online). Graphs show the mean RT (left), SD of RT (center), and the percentage of lapses (right) per block of trials. Error bars represent 95% CI of the mean

There were no significant correlations between the RT scores of phasic alertness, orienting, and executive control (see Table 5). In addition, Bayesian analysis demonstrated consistent evidence in favor of the absence of correlations between RT scores of the classic attentional functions. Altogether, these results provide additional empirical support for the independence between attentional components (Fan et al., 2002). Note that, critically, the correlations among the RT scores of the attentional components were very similar between the standard and the online ANTI-Vea.

Regarding the correlations among the classic attentional component scores computed from the percentage of errors (see Table 6), no significant correlations were found in the

standard ANTI-Vea, again with consistent evidence in favor of the absence of correlations demonstrated by Bayesian analyses. In the online ANTI-Vea, only executive control showed significant positive correlations with phasic alertness and orienting, observed as substantial and decisive evidence in favor of the existence of these correlations by the Bayesian analyses, respectively.

Importantly, as observed in Table 7, EV and AV showed large positive correlations between all the RT measures, with very strong or decisive evidence in favor of the existence of a correlation by Bayesian analyses. In addition, only the RT variability of the AV component demonstrated a significant negative correlation with hits and sensitivity (A') of EV,

Table 5 Bivariate Pearson and Bayesian correlations between the RT scores of the classic attentional networks components as a function of the task version (standard/online)

Attentional scores (RT)	Coefficient	Attentional scores (RT)		
		Overall	Phasic alertness	Orienting
Standard				
Phasic alertness	Pearson's r	.11*	—	
	BF ₁₀	0.50		
Orienting	Pearson's r	.01	.02	—
	BF ₁₀	0.07	0.08	
Executive control	Pearson's r	.09	.07	−.08
	BF ₁₀	0.24	0.16	0.18
Online				
Phasic alertness	Pearson's r	.01	—	
	BF ₁₀	0.08		
Orienting	Pearson's r	.13*	−.09	—
	BF ₁₀	0.71	0.24	
Executive control	Pearson's r	.05	.09	−.02
	BF ₁₀	0.11	0.25	0.08

Note. Inverse Bayes factors (BF₁₀) supporting either the H_0 (i.e., < 0.33) or the H_1 (i.e., > 3) are in boldface. RT = reaction time

* $p < .05$, ** $p < .01$, *** $p < .005$, **** $p < .001$

Table 6 Bivariate Pearson and Bayesian correlations between the percentages of error scores of the classic attentional networks components as a function of the task version (standard/online)

Attentional scores (errors)	Coefficient	Attentional scores (errors)		
		Overall	Phasic alertness	Orienting
Standard				
Phasic alertness	Pearson's r	.16*	—	
	BF ₁₀	3.27		
Orienting	Pearson's r	−.05	.08	—
	BF ₁₀	0.11	0.20	
Executive control	Pearson's r	.21****	.01	.01
	BF ₁₀	46.52	0.07	0.07
Online				
Phasic alertness	Pearson's r	.15*	—	
	BF ₁₀	1.81		
Orienting	Pearson's r	.08	.08	—
	BF ₁₀	0.17	0.17	
Executive control	Pearson's r	.18***	.17**	.24****
	BF ₁₀	7.62	3.84	292.73

Note. Inverse Bayes factors (BF₁₀) supporting either the H₀ (i.e., < 0.33) or the H₁ (i.e., > 3) are in boldface

* $p < .05$, ** $p < .01$, *** $p < .005$, **** $p < .001$

wherein strong evidence in favor of the existence of a correlation was observed by Bayesian analyses in the standard but not the online task. Importantly, the EV and AV components showed relative independence in the remaining measures, in

most cases with consistent evidence in favor of the absence of correlations by Bayesian analyses. Critically, the correlations between the EV and AV components were observed in the same vein for the standard and the online ANTI-Vea.

Table 7 Bivariate Pearson and Bayesian correlations between the executive and the arousal vigilance measures as a function of the task version (standard/online)

Arousal vigilance	Coefficient	Executive vigilance					
		Mean RT	SD of RT	Hits	FA	A'	B''
Standard							
Mean RT	Pearson's <i>r</i>	.47****	.22****	−.04	−.11	.00	.10
	BF ₁₀	4.70e+14	80.08	0.10	0.44	0.07	0.37
SD of RT	Pearson's <i>r</i>	.31****	.30****	−.20****	−.02	−.22****	.10
	BF ₁₀	165,549.9	63,444.71	42.81	0.08	98.76	0.28
Lapses	Pearson's <i>r</i>	.45****	.26****	−.03	−.02	−.03	.03
	BF ₁₀	2.06e+13	1755.32	0.08	0.08	0.08	0.08
Online							
Mean RT	Pearson's <i>r</i>	.43****	.23****	.09	.00	.09	−.06
	BF ₁₀	3.55e+11	202.45	0.26	0.07	0.25	0.12
SD of RT	Pearson's <i>r</i>	.39****	.40****	−.15*	−.06	−.15*	.11
	BF ₁₀	1.56e+9	3.67e+9	1.57	0.12	1.86	0.40
Lapses	Pearson's <i>r</i>	.50****	.24****	.10	.06	.07	−.10
	BF ₁₀	1.11e+17	482.40	0.28	0.12	0.14	0.31

Note. Inverse Bayes factors (BF₁₀) supporting either the H₀ (i.e., < 0.33) or the H₁ (i.e., > 3) are in boldface. RT = reaction time; SD = standard deviation; FA = false alarms

* $p < .05$, ** $p < .01$, *** $p < .005$, **** $p < .001$

Table 8 Bivariate Pearson and Bayesian correlations between the RT scores of the classic attentional networks components and the executive vigilance measures as a function of the task version (standard/online)

Attentional scores (RT)	Coefficient	Executive vigilance					
		Mean RT	SD of RT	Hits	FA	A'	B''
Standard							
Overall	Pearson's <i>r</i>	.68****	.45****	.52****	.33****	.43****	-.44****
	BF ₁₀	3.09e+39	2.77e+13	2.04e+19	2.94e+6	6.16e+11	1.06e+13
Phasic alertness	Pearson's <i>r</i>	.05	-.03	-.02	.03	-.04	-.01
	BF ₁₀	0.10	0.08	0.08	0.08	0.09	0.07
Orienting	Pearson's <i>r</i>	.01	-.04	.04	.03	.03	-.06
	BF ₁₀	0.07	0.09	0.09	0.09	0.08	0.13
Executive control	Pearson's <i>r</i>	.04	.09	-.04	-.13*	.01	.07
	BF ₁₀	0.09	0.22	0.09	0.81	0.07	0.15
Online							
Overall	Pearson's <i>r</i>	.74****	.55****	.40****	.36****	.23****	-.42****
	BF ₁₀	3.36e+47	2.59e+21	5.26e+9	4.54e+7	197.96	5.45e+10
Phasic alertness	Pearson's <i>r</i>	.06	.00	-.05	-.02	-.05	.03
	BF ₁₀	0.12	0.07	0.11	0.08	0.10	0.08
Orienting	Pearson's <i>r</i>	.13*	.07	.06	.04	.04	.01
	BF ₁₀	0.77	0.14	0.12	0.10	0.09	0.08
Executive control	Pearson's <i>r</i>	.05	-.01	-.07	.08	-.10	.02
	BF ₁₀	0.10	0.07	0.14	0.18	0.34	0.08

Note. Inverse Bayes factors (BF₁₀) supporting either the H₀ (i.e., < 0.33) or the H₁ (i.e., > 3) are in boldface. RT = reaction time; SD = standard deviation; FA = false alarms

* $p < .05$, ** $p < .01$, *** $p < .005$, **** $p < .001$

Notably, RT scores of the classic attentional components showed independence from the EV (see Table 8) and AV (see Table 9) measures, both by nonsignificant Pearson correlations and by consistent evidence in favor of the absence of correlations by Bayesian analyses. Altogether, although these findings are based on correlational analyses and therefore should be interpreted with some caution, this set of outcomes seems to support a relative independence between attentional and vigilance functions. Note that Bayesian correlations in particular provided decisive evidence in favor of the existence of a correlation between overall RT of the ANTI trials and all the EV/AV measures. Interestingly, as observed in Table 9, the phasic alertness score correlated positively with the AV measures only in the standard version, which was observed as very strong or decisive evidence for the existence of a correlation by Bayesian analyses. However, it is important to note that, as observed with the previous correlations described above, the correlations obtained in Table 8 and Table 9 were very similar for the two task versions.

Finally, as observed in Table 10, in both the standard and the online ANTI-Vea, the overall percentage of errors computed from the ANTI trials showed significant correlations with the FA, sensitivity, and response bias measures of EV—with decisive evidence in favor of the existence of these correlations by

Bayesian analyses—but not with the hits and the RT measures of EV, wherein consistent evidence in favor of the absence of a correlation was observed by Bayesian analyses. Interestingly, it can be observed in Table 10 that the higher the overall percentage of errors in the ANTI trials, the higher the FA rate, while a higher overall percentage of errors in the ANTI trials was associated with decreased sensitivity and a more liberal response criterion. Furthermore, note that the size of the executive control score seems to be negatively related to the percentage of hits, FA, and sensitivity, but positively related to the response bias: in all these correlations, Bayesian analyses demonstrated that evidence in favor of the existence of a correlation was either very strong or decisive. Lastly, the overall percentage of errors in the ANTI trials correlated positively with the RT variability in the AV component (see Table 11), with decisive evidence in favor of the existence of a correlation by Bayesian analyses, again in both task versions.

Split-half reliability indices

As can be observed in Table 12, the split-half reliability indices of the classic attentional functions and vigilance components were similar between the standard and the online ANTI-Vea. Note that, regarding the attentional scores, the reliability

Table 9 Bivariate Pearson and Bayesian correlations between the RT scores of the classic attentional networks components and the arousal vigilance measures as a function of the task version (standard/online)

Attentional scores (RT)	Coefficient	Arousal vigilance		
		Mean RT	SD of RT	Lapses
Standard				
Overall	Pearson's <i>r</i>	.39****	.23****	.40****
	BF ₁₀	2.41e+9	180.09	1.06e+10
Phasic alertness	Pearson's <i>r</i>	.26****	.21****	.22****
	BF ₁₀	1830.11	56.19	120.13
Orienting	Pearson's <i>r</i>	.12*	.02	.13*
	BF ₁₀	0.58	0.07	0.94
Executive control	Pearson's <i>r</i>	−.04	.01	−.04
	BF ₁₀	0.10	0.07	0.10
Online				
Overall	Pearson's <i>r</i>	.31****	.32****	.40****
	BF ₁₀	190,414.39	227,684.69	3.56e+9
Phasic alertness	Pearson's <i>r</i>	.08	.07	.08
	BF ₁₀	0.20	0.15	0.20
Orienting	Pearson's <i>r</i>	.05	.01	.03
	BF ₁₀	0.11	0.08	0.08
Executive control	Pearson's <i>r</i>	.02	.11	.03
	BF ₁₀	0.08	0.42	0.08

Note. Inverse Bayes factors (BF₁₀) supporting either the H₀ (i.e., < 0.33) or the H₁ (i.e., > 3) are in boldface. RT = reaction time; SD = standard deviation

* $p < .05$, ** $p < .01$, *** $p < .005$, **** $p < .001$

was higher in RT scores than in the error scores. Importantly, only the overall score of RT and errors showed acceptable reliability, with indices above or very close to .90 when considering the Spearman–Brown prophecy formula. Concerning the classic attentional function scores, the reliability of executive control was higher than that observed for phasic alertness and orienting (see Table 12).

Regarding the vigilance components, it can be observed in Table 12 that both task versions showed acceptable reliability in most of the EV and AV measures. Again, overall RT for EV and AV was above .90. In addition, the hit rate (EV component) and the percentage of lapses (AV component) also showed reliability above .90. Lastly, in the EV indices of FA, A', B'', and the SD of RT in the AV component, reliability of between .76 and .88 was observed, with small differences between the standard and the online task versions.

Discussion

In the present study, we collected data from a large sample by measuring the classic attentional functions and two components of vigilance (EV and AV), with either the standard (i.e.,

completed in typical lab conditions) or the online (i.e., performed through a website outside the lab) version of the ANTI-Vea task (Luna et al., 2018). By collecting such a large amount of data, we expected to achieve two main goals: (1) to examine whether the online ANTI-Vea is as effective as the standard ANTI-Vea (Luna et al., 2018) for assessing both the EV and AV decrement across time on task (Claypoole et al., 2018), along with the main effects and interactions of the classic attentional components; and (2) to examine the split-half reliability of the attentional and vigilance scores obtained by the two task versions. Thus, we expected the present study to provide novel and useful evidence for researchers interested in measuring the different components of attention with a valid and reliable method which, importantly, (1) is publicly available in an online website, (2) is easy to use in applied contexts, and (3) is less costly in time and economic resources for collecting data in large samples (Claypoole et al., 2018; Germine et al., 2012; Sassenberg & Ditrach, 2019).

For the sake of simplicity, the discussion will be presented as a function of four groups of results: (1) the main effects and interactions of the classic attentional components, (2) the EV and AV decrement across time on task, (3) the independence and correlations between attentional and vigilance components, and (4) the split-half reliability outcomes.

Table 10 Bivariate Pearson and Bayesian correlations between the percentage of error scores of the classic attentional networks components and the executive vigilance measures as a function of the task version (standard/online)

Attentional scores (errors)	Coefficient	Executive vigilance					
		Mean RT	SD of RT	Hits	FA	A'	B''
Standard							
Overall	Pearson's <i>r</i>	.00	.12*	−.04	.64****	−.36****	−.40****
	BF ₁₀	0.07	0.65	0.09	5.96e+32	5.48e+7	1.06e+10
Phasic alertness	Pearson's <i>r</i>	−.07	.03	−.12*	.02	−.16**	−.01
	BF ₁₀	0.15	0.08	0.57	0.08	3.29	0.07
Orienting	Pearson's <i>r</i>	−.05	−.02	−.20****	−.23****	−.12*	.21****
	BF ₁₀	0.10	0.08	41.72	209.44	0.73	71.82
Executive control	Pearson's <i>r</i>	−.02	.02	−.29****	−.20****	−.23****	.22****
	BF ₁₀	0.07	0.08	27,849.93	39.59	192.17	86.97
Online							
Overall	Pearson's <i>r</i>	.04	.11	−.06	.62****	−.42****	−.40****
	BF ₁₀	0.10	0.37	0.13	2.25e+29	6.57e+10	6.57e+9
Phasic alertness	Pearson's <i>r</i>	−.04	.03	−.15**	−.06	−.13*	.08
	BF ₁₀	0.09	0.08	2.11	0.13	0.79	0.19
Orienting	Pearson's <i>r</i>	−.10	−.17***	−.21****	−.17**	−.18****	.18***
	BF ₁₀	0.35	4.16	45.47	3.77	5.57	9.81
Executive control	Pearson's <i>r</i>	−.04	−.11	−.35****	−.24****	−.25****	.29****
	BF ₁₀	0.10	0.44	6.86e+6	493.17	1031.04	30,060.72

Note. Inverse Bayes factors (BF₁₀) supporting either the H₀ (i.e., < 0.33) or the H₁ (i.e., > 3) are in boldface. RT = reaction time; SD = standard deviation; FA = false alarms

* $p < .05$, ** $p < .01$, *** $p < .005$, **** $p < .001$

Measuring the classic attentional components in the lab and online

The typical main effects commonly observed for the classic attentional components with the ANTI (Callejas et al., 2004), the ANTI-V (Roca et al., 2011), and the ANTI-Vea (Luna et al., 2018) were replicated in the present study for both the standard and the online task. First, for the orienting network, the facilitation effect of cueing was observed as usual (i.e., valid < no cue < invalid; Posner, 2016) specifically in the RT, whereas in the analysis of errors, responses were more accurate in the no cue condition than in the valid and invalid conditions. Note that the cueing effects observed in RT and errors were observed in the same vein in both the standard and the online task, although they were perhaps slightly smaller in the online version. It is possible that such a difference between the two tasks could be due to the variability in the environmental conditions in which the online task was performed.

Second, for the executive control network, the effect of distractor interference typically reported with the flanker task (Eriksen & Eriksen, 1974; Funes, Lupiáñez, & Humphreys, 2010) was observed here for both RT and errors, with no differences between task versions. Note that the size of the interference observed with the ANTI-Vea (i.e., 44 ms in the RT for

both task versions, and 0.51% and 0.61% in the errors for the standard and the online versions, respectively) seems to be smaller than that usually reported with the ANT (Fan et al., 2002), ANTI (Callejas et al., 2004), and ANTI-V (Roca et al., 2011) tasks. To account for this reduced interference, we recently conducted a separate study to specifically address this issue (Luna, Telga, Vadillo, & Lupiáñez, 2020d). In short, and after analyzing data collected from five different experiments, we concluded that, in comparison with the interference effect observed when only performing a flanker task (i.e., ~55 ms and ~3.5% of errors), the concurrent working memory load of performing the flanker and the EV task at the same time (1) reduces interference (i.e., ~33 ms and ~0.5% of errors) when the EV task helps to perceptually segregate the target from distractors (i.e., detecting an infrequent vertical displacement of the target, as in the ANTI-Vea), but (2) increases interference (i.e., ~87 ms and ~10.0% errors) when the EV task boosts the perceptual grouping of the target and distractors (i.e., by detecting an infrequent horizontal displacement of the target, as in the previous ANTI-V; Roca et al., 2011) (Luna, Telga, et al., 2020d). In any case, a nice property of the scores of the classic attentional functions with the ANTI-Vea task is that the three are of a similar size (~45 ms), in contrast to previous versions of the task, which provide a much larger measure for executive

Table 11 Bivariate Pearson and Bayesian correlations between the percentage of error scores of the classic attentional networks components and the arousal vigilance measures as a function of the task version (standard/online)

Attentional scores (errors)	Coefficient	Arousal vigilance		
		Mean RT	SD of RT	Lapses
Standard				
Overall	Pearson's <i>r</i>	.07	.31****	.17****
	BF ₁₀	0.15	172,149.05	6.19
Phasic alertness	Pearson's <i>r</i>	.04	.16**	.09
	BF ₁₀	0.09	2.80	0.23
Orienting	Pearson's <i>r</i>	.02	.05	.02
	BF ₁₀	0.08	0.10	0.07
Executive control	Pearson's <i>r</i>	.01	.06	.01
	BF ₁₀	0.07	0.13	0.07
Online				
Overall	Pearson's <i>r</i>	.00	.30****	.12*
	BF ₁₀	0.07	51,119.35	0.53
Phasic alertness	Pearson's <i>r</i>	.07	.14*	.06
	BF ₁₀	0.16	1.36	0.13
Orienting	Pearson's <i>r</i>	−.01	.04	.01
	BF ₁₀	0.08	0.09	0.08
Executive control	Pearson's <i>r</i>	−.01	.13*	.00
	BF ₁₀	0.07	0.85	0.07

Note. Inverse Bayes factors (BF₁₀) supporting either the H₀ (i.e., < 0.33) or the H₁ (i.e., > 3) are in boldface. RT = reaction time; SD = standard deviation
 * $p < .05$, ** $p < .01$, *** $p < .005$, **** $p < .001$

control. Nevertheless, the nature of this reduced interference should be taken into account when using the ANTI-Vea to measure executive control in different populations.

Regarding phasic alertness, although the typical main effect of the warning signal (i.e., faster and more accurate responses in the tone than in the no tone condition; Posner, 2008) was observed with both the standard and the online ANTI-Vea, phasic alertness was slightly but significantly reduced when the task was administered online as compared to the standard version. It is indeed possible that this is due to some unknown conditions of the context in which participants completed the online task that are otherwise controlled in an experimental session conducted in the lab (e.g., environmental noise). Furthermore, participants used headphones to listen to the auditory warning signal tone in the lab, whereas in the online task they were only encouraged to set the sound level of the computer to 75%. These (and other possible factors) could underlie this unexpected effect, so in future studies we should control them to better disentangle this reduction in phasic alertness in the online assessment. However, although phasic alertness was slightly reduced in RT when assessed with the online task, note that (1) in the online ANTI-Vea, indeed, the tone produced a large effect, significantly improving RT in comparison to the no tone condition; and (2) task version did not modulate the phasic alertness effect in the percentage of errors.

Lastly, there was a main effect of task version for the overall RT in the ANTI trials, which was not observed for the overall percentage of errors. In general, responses were slower for the online version than the standard one. Again, it is probable that this overall difference in RT between task versions is due to the variability in the environmental conditions in which the online task was performed. For instance, and as recently stated by Claypoole et al. (2018), in an online session “it is impossible to know whether participants are completing the study cozily in bed or during a chaotic afternoon lecture” (p. 1349). Nevertheless, and critically, note that the typical interactions between the classic attentional components commonly reported with the ANTI task (Callejas et al., 2005, 2004) were also observed in the present study, and most importantly, almost all of them were not modulated by the task version.

Therefore, to sum up, except for the small considerations mentioned above, the online ANTI-Vea seems to be as effective as the standard ANTI-Vea for assessing the main effects and interactions of the classic attentional networks components.

The online ANTI-Vea is suitable for assessing the EV and AV decrement

One of the main challenges of the present study was to examine whether the vigilance decrement phenomenon in

Table 12 Mean split-half reliability correlations (Pearson's r) for the attentional networks and vigilance components measures. The Spearman–Brown formula extrapolates test–retest reliability from split-half correlations

	Standard		Online	
	Mean r [95% CI]	Spearman–Brown	Mean r [95% CI]	Spearman–Brown
Attentional scores (RT)				
Overall	.98 [.983, .983]	.99	.98 [.984, .984]	.99
Phasic alertness	.12 [.123, .125]	.22	.22 [.219, .221]	.36
Orienting	.18 [.179, .181]	.31	.18 [.177, .179]	.30
Executive control	.51 [.508, .510]	.67	.52 [.520, .521]	.68
Attentional scores (errors)				
Overall	.85 [.845, .846]	.92	.81 [.808, .808]	.89
Phasic alertness	.10 [.095, .097]	.18	.06 [.060, .062]	.11
Orienting	.03 [.030, .032]	.06	.17 [.164, .166]	.28
Executive control	.49 [.492, .493]	.66	.36 [.355, .357]	.52
Executive vigilance				
Mean RT (ms)	.91 [.907, .907]	.95	.94 [.940, .941]	.97
SD of RT (ms)	.58 [.579, .580]	.73	.55 [.553, .554]	.71
Hits (%)	.89 [.890, .891]	.94	.86 [.858, .859]	.92
False alarms (%)	.74 [.736, .737]	.85	.65 [.650, .651]	.79
Sensitivity (A')	.79 [.789, .790]	.88	.70 [.700, .701]	.82
Response Bias (B'')	.78 [.780, .781]	.88	.67 [.672, .673]	.80
Arousal vigilance				
Mean RT (ms)	.95 [.955, .955]	.98	.98 [.983, .983]	.99
SD of RT (ms)	.73 [.730, .731]	.84	.61 [.608, .609]	.76
Lapses (%)	.93 [.926, .926]	.96	.95 [.954, .955]	.98

Note. r = Pearson correlation; CI = confidence interval; RT = reaction time; SD = standard deviation

both the EV and AV components could be effectively assessed by performing the online ANTI-Vea outside the lab. Recently, Claypoole et al. (2018) argued that some of the main reasons that so few studies (Fortenbaugh et al., 2015; Ralph et al., 2015; Sadeh et al., 2011; Thomson et al., 2016) have measured vigilance (and in particular, the EV component) with online tasks might be that (1) in an online session, experimental conditions cannot be controlled as in the lab, and there could be some unexpected factors that might modulate vigilance performance (e.g., it has been demonstrated that mastication helps to reduce the vigilance decrement, see Miquel, Haddou, & Day, 2019; Morgan, Johnson, & Miles, 2014); and (2) as the task would be completed on different devices across participants, it is quite probable that the lack of perceptual uniformity in an online experiment (i.e., as a result of, for instance, different screen sizes or luminosity intensities across the sample) might have an uncontrolled but relevant influence on the vigilance performance (Hashimoto, Kumashiro, & Miyake, 2003). Notwithstanding these effects, in the same vein as previous online approaches (Fortenbaugh et al., 2015; Ralph et al., 2015; Sadeh et al., 2011; Thomson et al., 2016), we observed in the

current study that the online ANTI-Vea was as effective as the standard ANTI-Vea for assessing both the EV and AV decrement across time on task.

In particular, for the EV component, in both versions there was a significant and linear decrement in hits and FA across time on task, and consequently there was a small linear drop in sensitivity along with a relevant increment in the response bias. Interestingly, a small main effect of task version was found for both the mean and RT variability in the EV task, along with a main effect in the hits and the sensitivity. Most importantly, the linear trends for the different outcomes of the EV decrement were all observed in a very similar way for both the standard and the online ANTI-Vea, thus providing consistent evidence supporting the online ANTI-Vea as a suitable method for assessing the EV decrement.

Note that the EV decrement has been traditionally understood as a significant loss in sensitivity across time on task (See, Howe, Warm, & Dember, 1995; Warm, Parasuraman, & Matthews, 2008). However, a recent theoretical and empirical demonstration conducted by Thomson et al. (2016) argued that the shift across time on task in sensitivity and response bias might indeed be biased by a floor effect in the FA, i.e., an effect that is commonly observed in the traditional simple and

monotonic signal-detection tasks such as the SART (Robertson et al., 1997). In particular, Thomson et al. stated that if one were to observe the EV decrement as an increment in the response bias rather than as a loss in sensitivity, then the drop in hits would necessarily be accompanied by a similar drop in FA, something that is highly unlikely if FA are already at the floor in the first period of the task. Therefore, to avoid a floor rate in FA, we decided to compute FA in the ANTI-Vea only in the ANTI trials wherein it was more probable to observe a FA response, in the same vein as the empirical demonstration conducted by Thomson et al. and following the analytical method developed in a separate study in our lab (Luna et al., *in press*). Furthermore, and critically, note that the sensitivity loss effect observed in the present study seems to be dependent on the FA rate observed at the beginning of the task. Indeed, whereas a significant drop in sensitivity was still observed for participants ($n = 245$) showing a FA rate at the floor (i.e., equal to or less than 5%) in the first block [$F(5, 1215) = 29.56, p < .001, \eta_p^2 = .11, (.08, .14)$], no drop was observed for participants ($n = 346$) showing a FA rate higher than 5% in the first block [$F(5, 1720) = 1.40, p = .217, \eta_p^2 < .01, (.00, .01)$].

Regarding the AV component, the decrement across time on task was observed similarly to that typically reported using the PVT (Basner & Dinges, 2011; Lim & Dinges, 2008), in both the standard and the online ANTI-Vea: there was a significant and linear increment across time on task in the mean and RT variability as well as in the percentage of lapses. Interestingly, there was a significant main effect of task version for the mean RT and the percentage of lapses, as was observed in the ANTI and EV components: responses were slower in the online than in the standard task. As discussed above, it could be that the slowness in RT observed in general (i.e., in the ANTI, EV, and also AV trials) when completing the online version is due to unknown conditions in the environment, which are generally controlled in a typical experimental session (Claypoole et al., 2018). Furthermore, and critically, the AV decrement was not modulated by the task version, in either the mean RT, the RT variability (i.e., a very small interaction was found that was not confirmed in the analysis of the linear component), or the percentage of lapses. Thus, in summary, despite the overall differences observed in mean RT and the percentage of lapses, the AV decrement across time on task was observed equally with the online ANTI-Vea and the standard task.

The independence and correlations between attentional and vigilance components

The analysis of bivariate correlations between attentional and vigilance components was driven by three specific research questions regarding the cognitive processes modulated by the attentional networks system: (1) are the classic attentional

functions independent of one another (Petersen & Posner, 2012; Posner & Dehaene, 1994; Posner & Petersen, 1990); (2) are the EV and AV components independent of each other (Luna et al., 2018); and (3) is there any association between the classic attentional functions and vigilance components? Note that we have addressed these three issues by measuring the different attentional and vigilance components either in typical experimental conditions or with an online task performed outside the lab. Importantly, most of the significant and nonsignificant correlation patterns found were very similar between the standard and the online ANTI-Vea. In addition, Bayesian correlations demonstrated evidence in favor of either the absence or existence of correlations similarly for both the standard and online tasks.

First, regarding the independence of the classic attentional components, we did not find significant correlations between phasic alertness, orienting, and executive control, either in RT or in error scores (except for the online task, in which some significant medium positive correlations were found), a pattern of results that supports the relative independence of the three attentional networks (Petersen & Posner, 2012; Posner & Dehaene, 1994; Posner & Petersen, 1990). It is important to note that both the present study and previous research (Callejas et al., 2005; Fan et al., 2009; Roca et al., 2018) have consistently demonstrated that the classic attentional networks interact with each other. However, the amount of evidence collected regarding the interactions between attentional components at the behavioral level is not incompatible with the proposal that attentional components belong to independent neural systems with dissociable behavioral responses (Petersen & Posner, 2012; Posner, 2012; Posner & Petersen, 1990; Posner, Sheese, Odludas, & Tang, 2006). Indeed, several neuroimaging studies wherein the behavioral performance of attentional networks was measured with the ANT or similar tasks have reported independent functional (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Galvao-Carmona et al., 2014; Neuhaus et al., 2010) and structural (Ge et al., 2013; Luna, Lupiáñez, & Martín-Arévalo, 2020a; Niogi, Mukherjee, Ghajar, & McCandliss, 2010) brain connectivity for the alerting, orienting, and executive control networks. In the present study, by conducting both Pearson and Bayesian correlations with the performance scores of the attentional networks components, we aimed at providing further empirical evidence that the ANTI-Vea is a suitable task for assessing—both in the lab and in the online session—the independence of attentional networks components at the behavioral level.

Interestingly, note that in previous studies with relatively large sample sizes, some significant correlations were observed between attentional components with the ANT (MacLeod et al., 2010), the ANTI (Ishigami & Klein, 2010), or the ANTI-V (Roca et al., 2018). However, as noted above, it is important to take into account that the scores of the classic

attentional components computed with the ANTI-Vea have similar sizes (in particular for the RT measure, where the three scores are around 45 ms). In contrast, the previous versions of the task usually reported different sized scores, particularly for the executive control score, which has usually been observed to be twice the size of the phasic alertness and orienting scores (Fan et al., 2002; Ishigami & Klein, 2010; MacLeod et al., 2010; Roca et al., 2011, 2018). Therefore, it seems that the ANTI-Vea (i.e., both the standard and the online) might be a more appropriate task for assessing the independence between the classic attentional components (Petersen & Posner, 2012; Posner & Petersen, 1990) than previous versions of the task (Callejas et al., 2004; Fan et al., 2002; Roca et al., 2011).

Second, regarding vigilance, the present study provides novel and consistent evidence to further support an empirical dissociation between EV and AV (Luna et al., 2018). Note that, from a theoretical point of view, the EV component would be specifically involved in selecting a specific response for detecting rare but critical signals over long periods (Mackworth, 1948; See, Warm, Dember, & Howe, 1997; Thomson, Besner, & Smilek, 2015), whereas AV would be a component rather involved in sustaining a fast reaction to stimuli from the environment without much control over the executed responses (Basner & Dinges, 2011; Lim & Dinges, 2008). Importantly, in the current study we observed some large positive correlations between the RT measures of EV and AV, which were found as decisive evidence in favor of the existence of a correlation by Bayesian analyses. In addition, some small and medium correlations were observed between both the hits and sensitivity of EV and the SD of RT of AV, which can be interpreted as the lower the RT variability in AV, the higher the ability to detect infrequent signals in EV. However, the main finding that can be observed in Table 7 is that, critically, the SDT metrics (i.e., which are indeed the specific measures that describe the ability to detect infrequent signals) of the EV component seem to be quite unrelated to the RT measures computed for AV, a finding supported both by nonsignificant Pearson correlations and by consistent evidence in favor of the absence of a correlation by Bayesian analyses.

Importantly, recent research has already shown a clear dissociation between EV and AV at the neural (Luna, Román-Caballero, Barttfeld, Lupiáñez, & Martín-Arévalo, 2020c) and physiological (Sanchis, Blasco, Luna, & Lupiáñez, 2020) levels. In one study conducted with the standard ANTI-Vea, we observed that, whereas anodal transcranial direct current stimulation over the right frontoparietal network seemed to mitigate the EV, it did not affect the AV decrement (Luna, Román-Caballero, et al., 2020c). In another study the AV decrement was particularly modulated by caffeine intake, whereas exercise intensity accelerated only EV performance (Sanchis et al., 2020). In the present study, although the independence between vigilance components was analyzed by

correlational analyses, and therefore these outcomes should be interpreted with some caution, the pattern of correlations observed seems to further support that vigilance can be indeed considered as two behavioral dissociated components.

Finally, the correlation matrices reported in Tables 8, 9, 10, and 11 also seem to support relative independence between the attentional and vigilance components. Nonetheless, as mentioned above, this set of outcomes was obtained only by Pearson and Bayesian correlations, and therefore should be interpreted with some caution. Note that the current design of the ANTI-Vea is not adequate to specifically examine the potential interactions of the attentional networks components with the EV and/or the AV decrement. On the one hand, in the EV trials, the experimental conditions of the ANTI design are not balanced (i.e., EV trials are randomly selected without any control from the combination of warning signal, visual cue, and congruency conditions). Moreover, there might not be enough trials per experimental block to analyze the interactions of ANTI conditions with the EV decrement. On the other hand, in the AV trials, no warning signal or visual cue (no arrow stimuli as either target or flankers) is presented before the millisecond counter. Therefore, future studies should specifically analyze the potential interactions between attentional and vigilance components by, for instance, controlling the ANTI conditions in the EV trials. In the present study, we provide evidence based on correlation analyses regarding a relative independence between attentional and vigilance components at the behavioral level.

Regarding the correlations observed between attentional and vigilance component scores, the strongest correlation was found between the overall RT of the ANTI task and the scores of EV, which might account for a more general mechanism involved in the speed of responses when executing a specific response. Note that the overall RT of the ANTI task might be interpreted as an indicator of the general responsivity of the attentional networks system. Indeed, previous research has shown that overall RT of the ANT or the ANTI task is a behavioral indicator of, for instance, attentional heritability estimates (Fan et al., 2001), benefits of exercise activity on attentional performance (Huertas, Blasco, Moratal, & Lupiáñez, 2019), impairments in performance from total sleep deprivation (Roca et al., 2012), changes in childhood development (Rueda et al., 2004), or even differences in attentional functioning between multiple sclerosis patients and healthy adults (Ishigami, Fisk, Wojtowicz, & Klein, 2013).

Furthermore, and importantly, although the EV measures showed large correlations only with the overall RT of the ANTI task, no further correlations were observed between SDT metrics of EV and the scores computed for the classic attentional components (except for a small negative correlation between executive control and FA, for which Bayesian analysis showed inconsistent evidence either in favor of the absence or existence of a correlation). Note that, however, in

the analysis of error scores, some medium and large correlations between the attentional components and the SDT measures of EV were observed, all of them supported by strong to decisive evidence in favor of the existence of a correlation by Bayesian analyses. In particular, it was observed that the higher the overall errors in the ANTI task, (1) the higher the FA rate, (2) the lower the sensitivity, and (3) the more liberal the response bias, which indeed is a consequence of an increment in the FA rate.

Interestingly, a negative correlation was found between the executive control score computed from errors and hits for EV (which was observed as decisive evidence in favor of the correlation by Bayesian analysis): it seems that the higher the interference from distractors in selecting the target, the smaller the effectiveness in detecting infrequent targets. Furthermore, a larger interference effect for executive control in the analysis of errors was associated with lower sensitivity and a more conservative response criterion. Altogether, this set of outcomes might be explained following the resource-control model of vigilance (Thomson et al., 2015). In short, the resource-control model proposes that the vigilance decrement might be a consequence of a progressive decline in executive control to sustain attentional resources over extended periods for detecting infrequent critical signals. Therefore, as time on task progresses, the drop in executive control—necessary to voluntarily deploy attentional resources to the vigilance task performed at hand—would lead to a progressive increase in task-unrelated thoughts, along with a progressive loss in vigilance performance (i.e., a drop in hits, decreased sensitivity, and a more conservative response criterion) (Thomson et al., 2015).

Nevertheless, although the present findings might be explained by the resource-control model of vigilance, further research is necessary to disentangle the intrinsic relationship between executive control and EV performance as a function of time on task (Zholdassova, Kustubayeva, & Matthews, 2019). In this vein, it was recently proposed that executive control measured with the ANT does not decrease across time on task, an outcome that challenges the resource-control model (Zholdassova et al., 2019). However, it is important to note that the ANT does not provide a direct measure of vigilance, and therefore, it is not an adequate task to analyze the theoretical explanations of the vigilance decrement phenomenon. Therefore, future studies with the ANTI-Vea task might specifically examine the predictions stated by the resource-control model, by analyzing the executive control performance across time on task and its relation with the EV and/or AV decrement.

With regard to AV, the significant positive correlations observed between the overall RT/errors in the ANTI task and the AV measures were found to be decisive evidence in favor of the existence of correlations by Bayesian analysis. In

addition, and importantly, the phasic alertness score computed in the standard task (which was higher than in the online task) showed a positive correlation with the AV measures, again observed as decisive evidence in favor of the existence of a correlation by Bayesian analysis. Thus, it seems that the sustained levels of arousal over long periods (i.e., AV) are associated with the short increments of arousal (i.e., phasic alertness), a piece of data that might account for the relationship between two different mechanisms of the alerting network (Petersen & Posner, 2012; Posner, 2008). It is possible that the correlation between phasic alertness and AV was not observed in the online ANTI-Vea because of the reduced phasic alertness observed when performing the task outside the lab, which is probably related to unknown environmental factors (e.g., low volume of the warning signal or a noisier environment outside the lab than in a typical experimental session). Future research with the online ANTI-Vea might consider improving control of the presentation of warning signal by, for instance, suggesting participants use headphones when performing the task at home.

Therefore, in summary, although relevant correlations were found between the hits of EV and executive control, and between AV and phasic alertness, in general there seems to exist relative independence between the attentional and vigilance components, a pattern of data that was similarly observed in both the standard and the online ANTI-Vea.

The reliability of the standard and the online ANTI-Vea

Although it could be expected that measuring attentional and vigilance components outside the lab would be less reliable, notably, task versions showed very similar reliability for all the scores computed. Note that, critically, the results obtained here replicate previous findings of split-half reliability reported with the ANT (MacLeod et al., 2010) and the ANTI-V (Roca et al., 2018). In particular, while acceptable reliability was observed for the overall scores computed with the ANTI trials, the reliability indices for the classic attentional functions scores were observed as problematic. Regarding EV, we found acceptable reliability for both the mean RT and the SDT metrics scores, as was previously observed with the ANTI-V (Roca et al., 2018). Interestingly, note that the reliability of the nonparametric indices of sensitivity (A') and response bias (B'') with the ANTI-Vea seems to be higher than the reliability of the parametric indices (i.e., d' and β , respectively) computed with the ANTI-V task (Roca et al., 2018). Importantly, whereas further analyses demonstrated that reliability computed from nonparametric indices was indeed higher than reliability computed from d' and β in both the standard and online ANTI-Vea, the findings of the present study can also be interpreted as novel evidence that the EV

measure is more reliable in the ANTI-Vea than in the former version of the task (Roca et al., 2018). Finally, and also importantly, we observed acceptable reliability for most of the AV measures, again, in both the standard and the online version of the task (except for SD of RT, which showed borderline reliability in the online task). Therefore, in summary, here we provide consistent evidence that the ANTI-Vea task (administered either in the lab or as an online session) is highly reliable for the assessment of the EV and AV components, and is also at least as reliable as the ANT (MacLeod et al., 2010) and the ANTI-V (Roca et al., 2018) for the measurement of the classic attentional components.

Conclusions

The main conclusion from the present study is that the online ANTI-Vea is as effective as the standard ANTI-Vea for assessing the main effects and interactions of the classic attentional components, along with the EV and AV decrement across time on task. For researchers interested in administering the online ANTI-Vea outside the lab, it should be noted that slower overall responses and a smaller phasic alertness effect in RT can be observed in comparison to the ANTI-Vea administered in typical experimental conditions. Furthermore, note that the online ANTI-Vea is as suitable as the standard ANTI-Vea for assessing (1) the independence among phasic alertness, orienting, and executive control; (2) the independence between EV and AV; and (3) relatively strong independence between attentional and vigilance components. Lastly, and importantly, the split-half reliability indices of the online ANTI-Vea are notably similar to those computed with the standard ANTI-Vea, which provides further evidence regarding the feasibility of the online task for the assessment of attentional and vigilance components.

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Open practices statement The methods, analysis, and data sets generated and analyzed during the current study are available in the Open Science Framework repository, <https://osf.io/q85bu/>

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References

- Basner, M., & Dinges, D. F. (2011). Maximizing sensitivity of the psychomotor vigilance test (PVT) to sleep loss. *Sleep*, 34(5), 581–591. <https://doi.org/10.1093/sleep/34.5.581>
- Callejas, A., Lupiáñez, J., Funes, M. J., & Tudela, P. (2005). Modulations among the alerting, orienting and executive control networks. *Experimental Brain Research*, 167(1), 27–37. <https://doi.org/10.1007/s00221-005-2365-z>
- Callejas, A., Lupiáñez, J., & Tudela, P. (2004). The three attentional networks: on their independence and interactions. *Brain and Cognition*, 54(3), 225–227. <https://doi.org/10.1016/j.bandc.2004.02.012>
- Claypoole, V. L., Neigel, A. R., Fraulini, N. W., Hancock, G. M., & Szalma, J. L. (2018). Can vigilance tasks be administered online? A replication and discussion. *Journal of Experimental Psychology: Human Perception and Performance*, 44(9), 1348–1355. <https://doi.org/10.1037/xhp0000538>
- Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd). Hillsdale, NJ: Erlbaum.
- Conners, C. (2000). *Conners' Continuous Performance Test II*. Toronto, Canada: Multi-Health Systems.
- Cumming, G. (2014). The New Statistics: Why and How. *Psychological Science*, 25(1), 7–29. <https://doi.org/10.1177/0956797613504966>
- Draheim, C., Mashburn, C. A., Martin, J. D., & Engle, R. W. (2019). Reaction time in differential and developmental research: A review and commentary on the problems and alternatives. *Psychological Bulletin*, 145(5), 508–535. <https://doi.org/10.1037/bul0000192>
- Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics*, 16(1), 143–149. <https://doi.org/10.3758/BF03203267>
- Fan, J., Gu, X., Guise, K. G., Liu, X., Fossella, J., Wang, H., & Posner, M. I. (2009). Testing the behavioral interaction and integration of attentional networks. *Brain and Cognition*, 70(2), 209–220. <https://doi.org/10.1016/j.bandc.2009.02.002>
- Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. *NeuroImage*, 26(2), 471–479. <https://doi.org/10.1016/j.neuroimage.2005.02.004>
- Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience*, 14(3), 340–347. <https://doi.org/10.1162/089892902317361886>
- Fan, J., Wu, Y., Fossella, J. A., & Posner, M. I. (2001). Assessing the heritability of attentional networks. *BMC Neuroscience*, 2(1), 14. <https://doi.org/10.1186/1471-2202-2-14>
- Fortenbaugh, F. C., DeGutis, J., & Esterman, M. (2017). Recent theoretical, neural, and clinical advances in sustained attention research. *Annals of the New York Academy of Sciences*, 1396(1), 70–91. <https://doi.org/10.1111/nyas.13318>
- Fortenbaugh, F. C., Degutis, J., Germine, L., Wilmer, J. B., Grosse, M., Russo, K., & Esterman, M. (2015). Sustained attention across the life span in a sample of 10,000: Dissociating ability and strategy. *Psychological Science*, 26(9), 1497–1510. <https://doi.org/10.1177/0956797615594896>
- Fritz, C. O., Morris, P. E., & Richler, J. J. (2012). Effect size estimates: Current use, calculations, and interpretation. *Journal of Experimental Psychology: General*, 141(1), 2–18. <https://doi.org/10.1037/a0024338>
- Funes, M. J., Lupiáñez, J., & Humphreys, G. (2010). Analyzing the generality of conflict adaptation effects. *Journal of Experimental*

- Psychology: Human Perception and Performance*, 36(1), 147–161. <https://doi.org/10.1037/a0017598>
- Galvao-Carmona, A., González-Rosa, J. J., Hidalgo-Muñoz, A. R., Páramo, D., Benítez, M. L., Izquierdo, G., & Vázquez-Marrufo, M. (2014). Disentangling the attention network test: behavioral, event related potentials, and neural source analyses. *Frontiers in Human Neuroscience*, 8(813), 1–16. <https://doi.org/10.3389/fnhum.2014.00813>
- Ge, H., Yin, X., Xu, J., Tang, Y., Han, Y., Xu, W., ... Liu, S. (2013). Fiber pathways of attention subnetworks revealed with tract-based spatial statistics (TBSS) and probabilistic tractography. *PLoS ONE*, 8(11), e78831. <https://doi.org/10.1371/journal.pone.0078831>
- Germine, L., Nakayama, K., Duchaine, B. C., Chabris, C. F., Chatterjee, G., & Wilmer, J. B. (2012). Is the Web as good as the lab? Comparable performance from Web and lab in cognitive/perceptual experiments. *Psychonomic Bulletin & Review*, 19(5), 847–857. <https://doi.org/10.3758/s13423-012-0296-9>
- Gignac, G. E., & Szodorai, E. T. (2016). Effect size guidelines for individual differences researchers. *Personality and Individual Differences*, 102, 74–78. <https://doi.org/10.1016/j.paid.2016.06.069>
- Grier, J. B. (1971). Nonparametric indexes for sensitivity and bias: computing formulas. *Psychological Bulletin*, 75(6), 424–429. <https://doi.org/10.1037/h0031246>
- Harrell, F. E. J. (2018). Hmisc: Harrell Miscellaneous. R package version 4.1-1. Retrieved from <https://cran.r-project.org/package=Hmisc>
- Hashimoto, M., Kumashiro, M., & Miyake, S. (2003). Effects of Screen Size and Task Difficulty on Vigilance Performance of Older Adults. *Journal of UOEH*, 25(4), 375–386. <https://doi.org/10.7888/juoe.25.375>
- Hemphill, J. F. (2003). Interpreting the magnitudes of correlation coefficients. *American Psychologist*, 58(1), 78–79. <https://doi.org/10.1037/0003-066X.58.1.78>
- Huertas, F., Blasco, E., Moratal, C., & Lupiáñez, J. (2019). Caffeine intake modulates the functioning of the attentional networks depending on consumption habits and acute exercise demands. *Scientific Reports*, 9(1), 10043. <https://doi.org/10.1038/s41598-019-46524-x>
- Hunter, J. D. (2007). Matplotlib: A 2D graphics environment. *Computing In Science & Engineering*, 9(3), 90–95. <https://doi.org/10.1109/MCSE.2007.55>
- Ishigami, Y., Fisk, J. D., Wojtowicz, M., & Klein, R. M. (2013). Repeated measurement of the attention components of patients with multiple sclerosis using the Attention Network Test-Interaction (ANT-I): stability, isolability, robustness, and reliability. *Journal of Neuroscience Methods*, 216(1), 1–9. <https://doi.org/10.1016/j.jneumeth.2013.02.013>
- Ishigami, Y., & Klein, R. M. (2010). Repeated measurement of the components of attention using two versions of the Attention Network Test (ANT): stability, isolability, robustness, and reliability. *Journal of Neuroscience Methods*, 190(1), 117–128. <https://doi.org/10.1016/j.jneumeth.2010.04.019>
- Jarosz, A. F., & Wiley, J. (2014). What Are the Odds? A Practical Guide to Computing and Reporting Bayes Factors. *The Journal of Problem Solving*, 7(1), 2–9. <https://doi.org/10.7771/1932-6246.1167>
- JASP Team (2019). JASP (Version 0.11.1). Retrieved from <https://jasp-stats.org/>
- Kelley, K., & Preacher, K. J. (2012). On effect size. *Psychological Methods*, 17(2), 137–152. <https://doi.org/10.1037/a0028086>
- Lamond, N., Jay, S. M., Dorrian, J., Ferguson, S. a, Roach, G. D., & Dawson, D. (2008). The sensitivity of a palm-based psychomotor vigilance task to severe sleep loss. *Behavior Research Methods*, 40(1), 347–352. <https://doi.org/10.3758/BRM.40.1.347>
- Lim, J., & Dinges, D. F. (2008). Sleep Deprivation and Vigilant Attention. *Annals of the New York Academy of Sciences*, 1129(1), 305–322. <https://doi.org/10.1196/annals.1417.002>
- Luna, F. G., Barttfeld, P., Martín-Arévalo, E., & Lupiáñez, J. (in press). The ANTI-Vea task: analyzing the executive and arousal vigilance decrements while measuring the three attentional networks. *Psicológica*.
- Luna, F. G., Lupiáñez, J., & Martín-Arévalo, E. (2020a). Microstructural white matter connectivity underlying the attentional networks system. *Manuscript Submitted for Publication*.
- Luna, F. G., Marino, J., Roca, J., & Lupiáñez, J. (2018). Executive and arousal vigilance decrement in the context of the attentional networks: The ANTI-Vea task. *Journal of Neuroscience Methods*, 306, 77–87. <https://doi.org/10.1016/j.jneumeth.2018.05.011>
- Luna, F. G., Martín-Arévalo, E., Foa Torres, G., & Lupiáñez, J. (2020b). White matter connectivity underlying the attentional and vigilance components. *Manuscript in Preparation*.
- Luna, F. G., Román-Caballero, R., Barttfeld, P., Lupiáñez, J., & Martín-Arévalo, E. (2020c). A High-Definition tDCS and EEG study on attention and vigilance: Brain stimulation mitigates the executive but not the arousal vigilance decrement. *Neuropsychologia*, 142, 107447. <https://doi.org/10.1016/j.neuropsychologia.2020.107447>
- Luna, F. G., Telga, M., Vadillo, M. A., & Lupiáñez, J. (2020d). Concurrent working memory load may increase or reduce cognitive interference depending on the attentional set. *Journal of Experimental Psychology: Human Perception and Performance*, 46(7), 667–680. <https://doi.org/10.1037/xhp0000740>
- Mackworth, N. H. (1948). The Breakdown of Vigilance during Prolonged Visual Search. *Quarterly Journal of Experimental Psychology*, 1(1), 6–21. <https://doi.org/10.1080/17470214808416738>
- MacLeod, J. W., Lawrence, M. A., McConnell, M. M., Eskes, G. A., Klein, R. M., & Shore, D. I. (2010). Appraising the ANT: Psychometric and theoretical considerations of the Attention Network Test. *Neuropsychology*, 24(5), 637–651. <https://doi.org/10.1037/a0019803>
- Miquel, S., Haddou, M. Ben, & Day, J. E. L. (2019). A systematic review and meta-analysis of the effects of mastication on sustained attention in healthy adults. *Physiology & Behavior*, 202(January), 101–115. <https://doi.org/10.1016/j.physbeh.2019.01.003>
- Morgan, K., Johnson, A. J., & Miles, C. (2014). Chewing gum moderates the vigilance decrement. *British Journal of Psychology*, 105(2), 214–225. <https://doi.org/10.1111/bjop.12025>
- Munafò, M. R., Nosek, B. A., Bishop, D. V. M., Button, K. S., Chambers, C. D., Percie du Sert, N., ... Ioannidis, J. P. A. (2017). A manifesto for reproducible science. *Nature Human Behaviour*, 1(1), 0021. <https://doi.org/10.1038/s41562-016-0021>
- Neuhaus, A. H., Urbanek, C., Opgen-Rhein, C., Hahn, E., Ta, T. M. T., Koehler, S., ... Dettling, M. (2010). Event-related potentials associated with Attention Network Test. *International Journal of Psychophysiology*, 76(2), 72–79. <https://doi.org/10.1016/j.ijpsycho.2010.02.005>
- Niogi, S., Mukherjee, P., Ghajar, J., & McCandliss, B. D. (2010). Individual Differences in Distinct Components of Attention are Linked to Anatomical Variations in Distinct White Matter Tracts. *Frontiers in Neuroanatomy*, 4(2), 1–12. <https://doi.org/10.3389/neuro.05.002.2010>
- Pearce, J., Gray, J. R., Simpson, S., MacAskill, M., Höchenberger, R., Sogo, H., ... Lindeløv, J. K. (2019). PsychoPy2: Experiments in behavior made easy. *Behavior Research Methods*, 51(1), 195–203. <https://doi.org/10.3758/s13428-018-01193-y>
- Petersen, S. E., & Posner, M. I. (2012). The Attention System of the Human Brain: 20 Years After. *Annual Review of Neuroscience*, 35(1), 73–89. <https://doi.org/10.1146/annurev-neuro-062111-150525>
- Pirruccio, V. (2018). *Attentional networks and mindfulness: investigations through multiple indexes (Doctoral dissertation)*. Sapienza Università di Roma. Retrieved from https://iris.uniroma1.it/retrieve/handle/11573/1037839/536391/Tesi_dottorato_Pirruccio

- Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology*, 32(1), 3–25. <https://doi.org/10.1080/00335558008248231>
- Posner, M. I. (2008). Measuring Alertness. *Annals of the New York Academy of Sciences*, 1129(1), 193–199. <https://doi.org/10.1196/annals.1417.011>
- Posner, M. I. (2012). Imaging attention networks. *NeuroImage*, 61(2), 450–456. <https://doi.org/10.1016/j.neuroimage.2011.12.040>
- Posner, M. I. (2016). Orienting of Attention: Then and Now. *Quarterly Journal of Experimental Psychology*, 69(10), 1864–1875. <https://doi.org/10.1080/17470218.2014.937446>
- Posner, M. I., & Dehaene, S. (1994). Attentional networks. *Trends in Neurosciences*, 17(2), 75–79. [https://doi.org/10.1016/0166-2236\(94\)90078-7](https://doi.org/10.1016/0166-2236(94)90078-7)
- Posner, M. I., & Petersen, S. E. (1990). The Attention System of The Human Brain. *Annual Reviews of Neuroscience*, 13, 25–42. <https://doi.org/10.1146/annurev.ne.13.030190.000325>
- Posner, M. I., Sheese, B. E., Odludas, Y., & Tang, Y. (2006). Analyzing and shaping human attentional networks. *Neural Networks*, 19(9), 1422–1429. <https://doi.org/10.1016/j.neunet.2006.08.004>
- Psychology Software Tools, Inc. (2012). [E-Prime 2.0]. Retrieved from <http://www.pstnet.com>
- Puente-Ontanilla, J. M. (2018). Unpublished data.
- R Core Team. (2018). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from <https://www.r-project.org>
- Ralph, B. C. W., Thomson, D. R., Seli, P., Carriere, J. S. A., & Smilek, D. (2015). Media multitasking and behavioral measures of sustained attention. *Attention, Perception, and Psychophysics*, 77(2), 390–401. <https://doi.org/10.3758/s13414-014-0771-7>
- Robertson, I. H., Manly, T., Andrade, J., Baddeley, B. T., & Yiend, J. (1997). “Oops!”: performance correlates of everyday attentional failures in traumatic brain injured and normal subjects. *Neuropsychologia*, 35(6), 747–758. [https://doi.org/10.1016/S0028-3932\(97\)00015-8](https://doi.org/10.1016/S0028-3932(97)00015-8)
- Roca, J., Castro, C., López-Ramón, M. F., & Lupiáñez, J. (2011). Measuring vigilance while assessing the functioning of the three attentional networks: the ANTI-Vigilance task. *Journal of Neuroscience Methods*, 198(2), 312–324. <https://doi.org/10.1016/j.jneumeth.2011.04.014>
- Roca, J., Fuentes, L. J., Marotta, A., López-Ramón, M.-F., Castro, C., Lupiáñez, J., & Martella, D. (2012). The effects of sleep deprivation on the attentional functions and vigilance. *Acta Psychologica*, 140(2), 164–176. <https://doi.org/10.1016/j.actpsy.2012.03.007>
- Roca, J., García-Fernández, P., Castro, C., & Lupiáñez, J. (2018). The moderating effects of vigilance on other components of attentional functioning. *Journal of Neuroscience Methods*, 308, 151–161. <https://doi.org/10.1016/j.jneumeth.2018.07.019>
- Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P., & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologia*, 42(8), 1029–1040. <https://doi.org/10.1016/j.neuropsychologia.2003.12.012>
- Sadeh, A., Dan, O., & Bar-Haim, Y. (2011). Online assessment of sustained attention following sleep restriction. *Sleep Medicine*, 12(3), 257–261. <https://doi.org/10.1016/j.sleep.2010.02.001>
- Sanchis, C., Blasco, E., Luna, F. G., & Lupiáñez, J. (2020). Effects of caffeine intake and exercise intensity on executive and arousal vigilance. *Scientific Reports*, 10(1), 8393. <https://doi.org/10.1038/s41598-020-65197-5>
- Sassenberg, K., & Ditrich, L. (2019). Research in Social Psychology Changed Between 2011 and 2016: Larger Sample Sizes, More Self-Report Measures, and More Online Studies. *Advances in Methods and Practices in Psychological Science*, 251524591983878. <https://doi.org/10.1177/2515245919838781>
- See, J. E., Howe, S. R., Warm, J. S., & Dember, W. N. (1995). Meta-analysis of the sensitivity decrement in vigilance. *Psychological Bulletin*, 117(2), 230–249. <https://doi.org/10.1037/0033-2909.117.2.230>
- See, J. E., Warm, J. S., Dember, W. N., & Howe, S. R. (1997). Vigilance and Signal Detection Theory: An Empirical Evaluation of Five Measures of Response Bias. *Human Factors*, 39(1), 14–29. <https://doi.org/10.1518/001872097778940704>
- Shenhav, A., Botvinick, M. M., & Cohen, J. D. (2013). The expected value of control: an integrative theory of anterior cingulate cortex function. *Neuron*, 79(2), 217–240. <https://doi.org/10.1016/j.neuron.2013.07.007>
- Stanislaw, H., & Todorov, N. (1999). Calculation of signal detection theory measures. *Behavior Research Methods, Instruments, & Computers*, 31(1), 137–149. <https://doi.org/10.3758/BF03207704>
- StatSoft, Inc. (2007). STATISTICA (data analyses software system), version 8.0. Retrieved from <http://www.statsoft.com>
- Thomson, D. R., Besner, D., & Smilek, D. (2015). A resource-control account of sustained attention: Evidence from mind-wandering and vigilance paradigms. *Perspectives on Psychological Science*, 10(1), 82–96. <https://doi.org/10.1177/1745691614556681>
- Thomson, D. R., Besner, D., & Smilek, D. (2016). A critical examination of the evidence for sensitivity loss in modern vigilance tasks. *Psychological Review*, 123(1), 70–83. <https://doi.org/10.1037/rev0000021>
- Vogel, S. C., Esterman, M., DeGutis, J., Wilmer, J. B., Ressler, K. J., & Germine, L. T. (2020). Childhood Adversity and Dimensional Variations in Adult Sustained Attention. *Frontiers in Psychology*, 11(April), 1–9. <https://doi.org/10.3389/fpsyg.2020.00691>
- Wagenmakers, E.-J., Love, J., Marsman, M., Jamil, T., Ly, A., Verhagen, J., ... Morey, R. D. (2018). Bayesian inference for psychology. Part II: Example applications with JASP. *Psychonomic Bulletin & Review*, 25(1), 58–76. <https://doi.org/10.3758/s13423-017-1323-7>
- Warm, J. S., Parasuraman, R., & Matthews, G. (2008). Vigilance Requires Hard Mental Work and Is Stressful. *Human Factors*, 50(3), 433–441. <https://doi.org/10.1518/001872008X312152>
- Wickham, H. (2011). The Split-Apply-Combine Strategy for Data Analysis. *Journal of Statistical Software*, 40(1), 1–29. <https://doi.org/10.18637/jss.v040.i01>
- Zholdassova, M., Kustubayeva, A., & Matthews, G. (2019). The ANT Executive Control Index: No Evidence for Temporal Decrement. *Human Factors*, 001872081988005. <https://doi.org/10.1177/0018720819880058>

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