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Research article

Executive and arousal vigilance decrement in the context of the attentional networks: The ANTI-Vea task

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ABSTRACT

Background: Vigilance is generally understood as the ability to detect infrequent critical events through long time periods. In tasks like the Sustained Attention to Response Task (SART), participants tend to detect fewer events across time, a phenomenon known as "vigilance decrement". However, vigilance might also involve sustaining a tonic arousal level. In the Psychomotor Vigilance Test (PVT), the vigilance decrement corresponds to an increment across time in both mean and variability of reaction time.

New Method: The present study aimed to develop a single task –Attentional Networks Test for Interactions and Vigilance – executive and arousal components (ANTI-Vea)– to simultaneously assess both components of vigilance (i.e., the executive vigilance as in the SART, and the arousal vigilance as in the PVT), while measuring the classic attentional functions (phasic alertness, orienting, and executive control).

Results: In Experiment #1, the executive vigilance decrement was found as an increment in response bias. In Experiment #2, this result was replicated, and the arousal vigilance decrement was simultaneously observed as an increment in reaction time.

Comparison with Existing Method: The ANTI-Vea solves some issues observed in the previous ANTI-V task with the executive vigilance measure (e.g., a low hit rate and no vigilance decrement). Furthermore, the new ANTI-Vea task assesses both components of vigilance together with others typical attentional functions.

Conclusions: The new attentional networks test developed here may be useful to provide a better understanding of the human attentional system. The role of sensitivity and response bias in the executive vigilance decrement are discussed.

1. Introduction

In the last 15 years, there has been considerable interest in developing behavioral tasks to assess several attentional functions simultaneously, such as the Attentional Network Test and its variations (Fan et al., 2002; Ishigami et al., 2016; MacLeod et al., 2010). However, vigilance has been only lately included in these tasks as a direct and independent measure (i.e., the ANTI-V task, by Roca et al. (2011)). Assessing vigilance can be quite complex when variables such as task demands, engagement, and time on task are took into account (Thomson et al., 2015). Besides, vigilance might not be a unitary concept. Whilst this process is frequently described as the ability to detect critical events through long time periods (Warm et al., 2008), there are several studies that conceive vigilance as sustaining the tonic arousal level that is necessary to react quickly to stimuli from the environment (see, for example, Basner et al. (2013)). Thus, in the present study, we have developed a new version of the attentional networks test (the ANTI-Vea), aiming at assessing independently these two components of vigilance, while measuring at the same time the classic attentional functions (i.e., phasic alertness, orienting, and executive control). We expect that the ANTI-Vea will contribute to the study of the attentional networks in different contexts and situations.

Abbreviations: EV, Executive Vigilance; AV, Arousal Vigilance

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1.1. The human attentional system

Posner and collaborators proposed that the attentional system is organized by three independent neural networks, that may interact with each other (Fan and Posner, 2004; Petersen and Posner, 2012; Posner and Dehaene, 1994; Posner and Petersen, 1990). First, the posterior orienting network involves the pulvinar nuclei of the thalamus and the superior colliculus, together with the temporo-parietal junction and the frontal eye fields. The orienting network directs attention towards potential spatial sources of relevant stimuli, and benefits from spatial cues that predict correctly these locations (Posner, 2014). Second, the alertness network is modulated by noradrenergic innervations of the locus coeruleus towards parietal and frontal regions in the right hemisphere. This network regulates two different functions: (a) phasic alertness, as a momentary increment of alertness produced by warning signals; and (b) vigilance, as the tonic alertness necessary to sustain performance over long time periods (Posner, 2008). Finally, the executive control network involves the anterior cingulate and the dorsolateral prefrontal cortices. In conflictive situations, this system regulates behavior to achieve our long-term goals (Funes et al., 2010; Shenhav et al., 2013).

In order to obtain an independent measure of each attentional network at the same time, Fan and collaborators developed the Attentional Network Test (ANT; Fan et al., 2002). This task consists in a flanker task, in which participants are to respond to the direction pointed by a central arrow (target) while ignoring the flanking arrows, which is useful to assess the executive control network (Botvinick et al., 2001; Eriksen and Eriksen, 1974). Additionally, for measuring phasic alertness, these stimuli can be preceded by a visual warning signal (i.e., double asterisk), or by no signal. Moreover, to assess the orienting network, stimuli can be anticipated by a spatial cue (i.e., an asterisk informing the correct location of the target) or a central cue (i.e., an asterisk without spatial information). Later on, aiming to analyze the interactions between the attentional networks, Callejas et al. (2004) dissociated the stimuli for measuring phasic alertness and orienting. In the ANT for Interactions (ANTI) task, an auditory tone is used as warning signal. In addition, the 100% predictive spatial cue is replaced by a visual non-predictive cue that indicates either the correct location of the target (valid cueing), or the opposite location (invalid cueing).

Interestingly, neither the ANT nor the ANTI included a direct measure of vigilance across time. Some studies proposed that overall performance, or the difference between the last and first block of trials, could be taken as indirect indexes of vigilance (Callejas et al., 2005; Ishigami and Klein, 2010). Thus, to provide a direct measure of this function, Roca and colleagues developed the ANTI-Vigilance task (ANTI-V; Roca et al., 2011). While solving the main flanker task, participants must remain vigilant to detect a low proportion of trials (25%) where the target appears largely displaced from its central position, either leftwards or rightwards. The ANTI-V proved to be useful to analyze the attentional functioning under total sleep deprivation (Roca et al., 2012) and to study drivers' attentional performance (Roca et al., 2013a, 2013b).

1.2. The multiple concept of vigilance

Vigilance is usually defined as the ability to sustain attention for detecting rare but critical events (see for example, See et al., 1997; Warm et al., 2008). To assess its functioning, psychologists have developed many behavioral tasks, like the Sustained Attention to Response Task (SART; Robertson et al., 1997), the Continuous Performance Test (Conners, 2000), or the Mackworth Clock Test (Lichstein et al., 2000). For example, in the SART, participants must watch and respond continuously to the presentation of any of the nine digits (0–9), while inhibiting the response to a pre-specified target digit (e.g., 3). Thus, participants have to decide constantly whether to execute a recurrent response, or to inhibit it and provide no response. Therefore, this set of tasks seems to analyze an 'executive' component of vigilance, focused on the accuracy in the detection of an infrequent target and the inhibition of a frequent response.

In the above-mentioned studies, the executive vigilance decrement is generally found as a tendency to detect less critical events across time (e.g., see Helton and Russell (2015)). There has been a long-standing discussion about whether this decrement is due to a loss in the sensitivity to discriminate unusual from usual events, or to a change in the response bias (Langner and Eickhoff, 2013; See et al., 1995). A recent review and an experimental demonstration conducted by Thomson et al. (2016) has shown that the decrement would be related to an increment in the response bias towards a more conservative criterion (i.e., participants attempt to commit fewer errors as time progresses).

On the other hand, vigilance also involves other aspects of behavior beyond the accuracy in detecting infrequent target. For example, in clinical neuropsychology, the term vigilance usually refers to the different levels of arousal during the sleep-wake cycle, without being associated with behavioral responsiveness (Oken et al., 2006). Accordingly, the Psychomotor Vigilance Test (PVT) is a behavioral task developed to analyze the maintenance of arousal through time (Lim and Dinges, 2008). The PVT requires the participants to stop, as fast as possible, a counter that appears on intervals from 2 to 10 s over a 10 min period (Basner and Dinges, 2011). Using this paradigm, the vigilance decrement is observed as a progressive increment in both the mean and the variability of reaction time, usually analyzed under conditions of sleep deprivation (Basner et al., 2011; Loh et al., 2004). Therefore, this 'arousal' component of vigilance would be more involved in achieving and sustaining fast reactions to stimuli, without much control, i.e., without the consideration of alternative response options.

1.3. Objectives of the current study

In a recent review by Tkachenko and Dinges (2018), they state that "rigorous behavioral tasks capable of dissociating the different aspects of attention across varying levels of cognitive demand is imperative to understanding the relationship between the brain and behavior" (p. 44). This was the main goal of the current study. We have developed the Attentional Networks Test for Interactions and Vigilance – executive and arousal components (ANTI-Vea). With this new version of the attentional networks test, we aimed at solving previous issues in the assessment of executive vigilance (EV), and to incorporate a direct measure of arousal vigilance (AV), while measuring the classic attentional functions (i.e., phasic alertness, orienting, and executive control). Furthermore, with this novel task, we expected to observe the decrement across time in the two vigilance components in a single administration.

Note that in previous studies with the ANTI-V, despite the vigilance measure being sensitive to total sleep deprivation (Roca et al., 2012), the performance decrement could not be observed under regular sleep conditions. Furthermore, assessment of vigilance in the ANTI-V is only related to the executive component, as it requires detecting the appearance of an infrequent target (like in the SART). Besides, this measure has shown several issues in previous studies. To start with, the vigilance task was quite challenging, even for young, non-clinical participants. The average hit rate was between 45% and 60%, either using cars (Casagrande et al., 2017; Marotta et al., 2015; Roca et al., 2013a, 2013b, 2012, 2011) or arrows as stimuli. In fact, participants tend to assume a very conservative response criterion (e.g., β between 7.5 and 10.3). Additionally, when the task was administered to older adults, about 44% of the sample had to be excluded due to an extremely poor performance (Moratal et al., 2015).

Thus, in a first experiment, we present a new version of the ANTI-V that we expected to be easier to perform than the previous version by Roca et al. (2011). This easier version will be more suitable to be used in populations for whom the previous version was not particularly fitted, such as older people (Moratal et al., 2015). In particular, we aimed to achieve a higher hit rate, and to observe the executive vigilance decrement within a single session. Next, in a second experiment, we present the ANTI-Vea, which incorporates an arousal vigilance measure, separated from the executive vigilance component. In both experiments, we decided to use arrows as stimuli (like in the ANT or ANTI tasks), as previous research has shown similar results in comparison to the original ANTI-V with cars (Bukowski et al., 2015; Morales et al., 2015).

2. Experiment #1: Improving the executive vigilance measure

Our main goal in Experiment #1 was to overcome some limitations in previous studies with the ANTI-V, such as the low proportion of hits (Bukowski et al., 2015; Morales et al., 2015; Roca et al., 2013a, 2013b, 2012, 2011). Thus, we compared vertically with horizontally displaced infrequent targets to assess vigilance. We expected the vertical displacement version to be easier to perform, as it will preclude the grouping of the target with the distracters, and thus infrequent targets would be more salient (see Fig. 1 in Section 3.3). Finally, we expected this new version of the task to be suitable to observe the executive vigilance decrement across time. Following Thomson et al. (2016), the decrement was expected to be observed as a change in the response bias towards a more conservative criterion, rather than as a loss in sensitivity.

3. Materials and methods

3.1. Participants

Participants (n = 51; 44 females) were students at the University of Granada, Spain (age: between 18 and 40 years, M = 19.72, SD = 2.11; education years: M = 13.88, SD = 0.98), who received course credits for their collaboration. They were randomly assigned to one of two groups, according to the task version administered (horizontal or vertical). Groups did not differ in age [*t* (48) = −0.09, *p* = .924] or education years [*t* (48) = 0.03, *p* = .972].

In this and the following experiment, participants were voluntarily recruited, and individually evaluated. All of them had normal or corrected to normal vision, and signed a written informed consent. 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 approved by the University of Granada Ethical Committee (175/CEIH/2017).

3.2. Apparatus and stimuli

Scripts were designed and run in E-Prime v2.0 Professional (Psychology Software Tools, Pittsburgh, PA). Responses were registered using a standard keyboard. The following stimuli were used: a black fixation cross (~7 pixels, px), a black asterisk (~13 px), a warning tone (2000 Hz), and five black arrows (50 px wide x 23 px high each arrow), pointing either leftwards or rightwards. Each arrow was horizontally separated by ~63 px from the adjacent arrows. In each trial, a random variability of ± 2 px was applied on the horizontal and the vertical position of each arrow, to make more difficult the detection of the displaced infrequent targets. In executive vigilance trials, the central arrow displacement was larger and fixed to 8 p×. The vertical and horizontal task versions were identical, except for the direction of the target displacement in the executive vigilance trials (see Fig. 1).

3.3. Procedure and design

The ANTI-V includes two different type of trials: ANTI trials (i.e., the main flanker task for assessing phasic alertness, orienting, executive control, and their interactions) and executive vigilance (EV) trials, which require detecting infrequent stimuli. Stimuli sequence and timing for each type of trial is shown in Fig. 1. In the ANTI trials (75%), participants had to respond according to the direction of the target ("C" for left, and "M" for right), while ignoring the flanking arrows. A warning signal and visual cue could anticipate the arrow appearance (see Fig. 1). The EV trials (25%) followed the same procedure, except that the target was horizontally or vertically displaced from the central position (see Fig. 1). In the EV trials, participants had to detect the large displacement by pressing the space bar, while ignoring the direction of the target.

Instructions and practice blocks (with visual feedback) were given

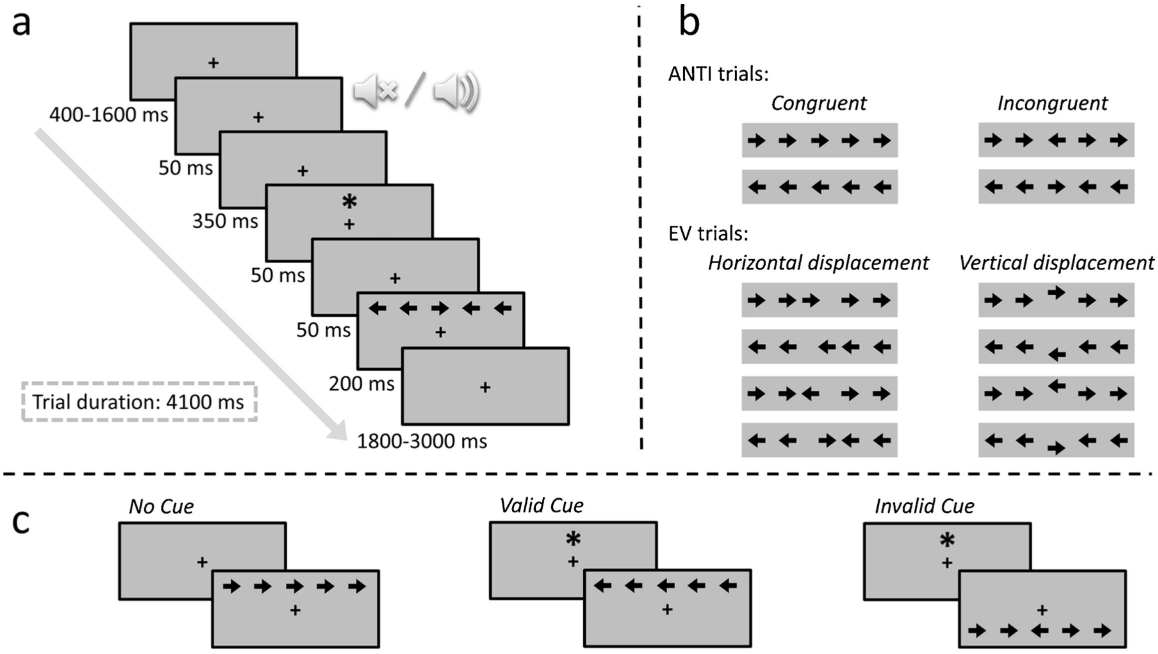

Fig. 1. Experimental procedure and stimuli sequence. (a) Procedure of both ANTI and EV trials. The exact duration of the initial fixation point was randomly assigned. The final fixation point remained on screen until total trial time achieved 4100 ms. Responses were allowed until 2000 ms since the target presentation. (b) Target and flankers for ANTI and EV trials in the horizontal and the vertical task versions. (c) Examples of Visual cue conditions.

gradually, which is also an improvement from the original ANTI-V (Roca et al., 2011). Participants were encouraged to keep their eyes on the fixation point all the time. First, standard instructions for the ANTI trials were given, followed by 16 practice ANTI trials. Next, instructions for the EV trials were presented, followed by 32 practice trials (including 16 ANTI and 16 EV in randomized order). Finally, participants performed an additional practice block of 32 randomized trials without feedback (24 ANTI and 8 EV; which is half of one experimental block). Then, before starting the experimental trials, participants could consult the researcher in charge any doubt about instructions, or repeat the last practice block.

The session included six experimental blocks of 64 randomized trials (48 ANTI and 16 EV per block), with no break and no feedback. The 48 ANTI trials had the following factorial design: Warning signal (No tone/Tone) × Visual Cue (Invalid/No Cue/Valid) × Congruency (Congruent/Incongruent). In the EV trials, one more factor was added to the previous design: Displacement direction (Left/Right or Up/Down, respectively for the horizontal or the vertical task version). The 16 EV trials per block were randomly selected from all the possible trial combinations.

3.4. Data analysis

Analyses were conducted in Statistica 8.0 (StatSoft Inc.), and data figures were made with Matplotlib 1.5.3 (Hunter, 2007) software. In all the analyses, the significance level was established at .05, and confidence intervals at 95%. A participant with more than 25% of errors (i.e., a performance unusually low for the typical ANTI task), and another participant with an extreme average reaction time (which was above 2.5 standard deviations from the group mean), were excluded from further analysis. In addition, one more participant was excluded due to technical issues. Thus, the final sample included 24 participants per group.

For the analysis of RT, trials with incorrect responses (7.08%) or with a RT smaller than 200 ms or higher than 1500 ms (2.16%) were excluded. Then, for the ANTI trials, repeated measures ANOVAs were conducted on both RT and percentage of errors, including Warning signal (No tone/Tone), Visual cue (Invalid/No cue/Valid), and Congruency (Congruent/Incongruent) as within-participants factors, and Task version (Horizontal/Vertical) as a between-participants factor.

For the EV trials, data from the different conditions of the warning signal, visual cue, and congruency variables were collapsed. Then, Signal Detection Theory metrics (SDT; Stanislaw and Todorov, 1999) were computed per block of trials, in order to analyze vigilance changes across time. Hits were calculated as the proportion of displaced targets detected correctly, and False Alarms (FAs) as the proportion of space bar responses (i.e., the response for infrequent stimuli) given to non-displaced targets. Next, non-parametric indexes of sensitivity (A') and response bias (B") were obtained (Grier, 1971). The non-parametric indexes are distribution-free, and can be fitted to the data without assuming a normal distribution (as with *d'* and β). Therefore, A' and B" can be perfectly computed when hits have a ceiling (i.e., 100%) and FAs a floor effect (i.e., 0%), without needing to replace those scores (Stanislaw and Todorov, 1999; Thomson et al., 2016). Last, mean and standard deviation (SD) of RT was obtained only for hits. Then, six repeated measures ANOVAs were separately conducted including Block (6 levels) as within-participants factors, and Task Version (Horizontal/Vertical) as a between-participants factor, one for each dependent variable: Hits, FAs, A' (sensitivity), B" (response bias), mean RT, and the SD of RT.

4. Results

4.1. Phasic alertness, orienting and executive control

Mean RT and accuracy for each ANTI condition are shown in Table 1.

4.1.1. Reaction time

Significant main effects were found for the three within-participants factors: Warning signal [F (1,46) = 109.40, $p < .001$, $\eta_p^2 = .70$], Visual cue [F (2, 92) = 42.36, $p < .001$, $\eta_p^2 = .48$], and Congruency [F (1,46) = 159.75, $p < .001$, $\eta_p^2 = .77$]. A main effect of Task Version was also observed [F (1,46) = 7.51, $p = .008$, $\eta_p^2 = .14$], with lower RT for the Vertical (M = 603 ms; SD = 88) than for the Horizontal version (M = 669 ms; SD = 84).

The following interactions were also significant: Warning signal × Visual cue [F (2, 92) = 12.03, $p < .001$, $\eta_p^2 = .21$], Warning signal × Congruency [F (1,46) = 19.54, $p < .001$, $\eta_p^2 = .30$], and Visual cue × Congruency [F (2, 92) = 5.53, $p = .005$, $\eta_p^2 = .11$]. The three within-participants factors did not interacted significantly [F (2, 92) = 1.99, $p = .141$, $\eta_p^2 = .04$]. Finally, Task Version only interacted with Congruency [F (1,46) = 24.34, $p < .001$, $\eta_p^2 = .35$]. The interference effect (i.e., incongruent minus congruent conditions) was smaller for the Vertical (37 ms) than for the Horizontal version (83 ms).

4.1.2. Accuracy (% of errors)

Significant main effects were found for Warning signal [F (1,46) = 7.80, $p = .007$, $\eta_p^2 = .14$] and Congruency [F (1,46) = 51.23, $p < .001$, $\eta_p^2 = .53$], but not for Visual cue [F (2, 92) 1.56, $p = .215$, $\eta_p^2 = .03$]. The main effect of Task Version was also observed [F (1,46) = 15.03, $p < .001$, $\eta_p^2 = .24$], with fewer errors for the Vertical (M = 3.89%; SD = 3.10) than for the Horizontal version (M = 8.99%; SD = 5.65).

Congruency interacted with Task Version [F (1,46) = 33.02, $p < .001$, $\eta_p^2 = .41$], like in the RT results. Again, the interference effect was smaller for the Vertical (1.01%) than for the Horizontal version (9.26%). The remaining interactions did not reach the significance level, except for Visual cue × Task Version [F (2, 92) = 5.83, $p = .004$, $\eta_p^2 = .41$]. In the Vertical version, the facilitation effect of cueing was found as usual (valid = 3.38%; no cue = 4.07%; invalid = 4.21%), whereas in the Horizontal version responses were less accurate for valid cue trials than for the remaining ones (valid = 10.19%; no cue = 9.07%; invalid = 7.72%).

4.2. Executive vigilance decrement

4.2.1. Reaction time

The main effect of Block were not significant neither for mean RT [F (5, 215) = 1.84, $p = .106$, $\eta_p^2 = .04$] nor for the SD of RT [F (5, 210) = 1.23, $p = .294$, $\eta_p^2 = .03$]. The main effect of Task version was only found for mean RT [F (1,43) = 13.85, $p < .001$, $\eta_p^2 = .24$], with faster RT for the Vertical (M = 738 ms; SD = 95) than for the Horizontal version (M = 845 ms; SD = 95). No significant interactions were observed.

4.2.2. Hits and false alarms

Both Hits [F (5, 230) = 5.81, $p < .001$, $\eta_p^2 = .11$] and FAs [F (5, 230) = 3.72, $p = .002$, $\eta_p^2 = .07$] showed a significant decrement across Blocks, as observed in Fig. 2. Additionally, main effects of Task Version were observed for both Hits [F (1,46) = 4.10, $p = .048$, $\eta_p^2 = .08$] and FAs [F (1,46) = 14.55, $p < .001$, $\eta_p^2 = .24$]. Hits rate was higher in the Vertical (M = 61.84%; SD = 19.24) than in the Horizontal version (M = 51.04%; SD = 17.71), whereas FAs rate was lower in the Vertical (M = 2.31%; SD = 2.92) than in the Horizontal version (M = 6.85%; SD = 5.04). No significant interactions were found.

4.2.3. Sensitivity and response bias

As observed in Fig. 2, a significant increment across Blocks was found for Response Bias (B") [F (5, 230) = 4.59, $p < .001$, $\eta_p^2 = .09$], while Sensitivity (A') did not change significantly [F (5, 230) = 0.84,

Table 1
Mean and standard deviation (in parentheses) for correct RT and accuracy (percentage of errors) of Experiment 1 for each condition of the ANTI factorial design in the horizontal and vertical ANTI-V versions: Warning signal (No tone/Tone) × Visual cue (Invalid/No cue/Valid) × Congruency (Congruent/Incongruent).

		No tone			Tone		
		Invalid	No cue	Valid	Invalid	No cue	Valid
Reaction Time							
Horizontal	Congruent	645 (74)	666 (92)	634 (94)	630 (85)	609 (91)	596 (79)
	Incongruent	739 (103)	722 (94)	709 (107)	737 (97)	691 (101)	683 (101)
Vertical	Congruent	617 (106)	625 (90)	589 (97)	587 (108)	549 (85)	543 (79)
	Incongruent	655 (90)	644 (91)	612 (89)	634 (102)	608 (88)	577 (85)
Accuracy							
Horizontal	Congruent	3.8 (6.0)	5.4 (5.6)	6.4 (7.4)	3.5 (4.2)	2.8 (4.9)	4.3 (5.7)
	Incongruent	13.0 (9.1)	14.6 (10.3)	15.5 (11.8)	10.6 (8.7)	13.5 (9.5)	14.6 (10.8)
Vertical	Congruent	4.0 (4.0)	4.0 (4.8)	3.8 (5.2)	2.8 (4.5)	3.1 (4.8)	2.6 (4.4)
	Incongruent	5.0 (5.2)	6.6 (5.5)	4.0 (6.1)	5.0 (8.1)	2.6 (3.4)	3.1 (3.9)

p = .522, η_p^2 = .02]. The analysis of Sensitivity showed a main effect of Task Version [F (1,46) = 14.93, p < .001, η_p^2 = .24], with higher sensitivity in the Vertical (A' = .89) than in the Horizontal version (A' = .84). Response Bias did not differ significantly between Task Versions [F (1,46) = 2.38, p = .129, η_p^2 = .05] (Vertical B" = .77; Horizontal B" = .59). No significant interactions were found.

5. Discussion

The first experiment aimed at improving the measurement of the executive component of vigilance in the ANTI-V. We expected the vertical displacement of the target to be more easily detected than the horizontal displacement of the original ANTI-V by Roca et al. (2011). In addition, with this manipulation, we expected to succeed in observing the vigilance decrement across time, which was not found previously with this task (Roca et al., 2012). Finally, we predicted no differences in the classic attentional measures between the two task versions.

The obtained results demonstrate that the vertical version of the task is more suitable to assess executive vigilance. Specifically, we found a higher percentage of hits and fewer FAs, and thus higher sensitivity than with the horizontal version. In previous studies with the ANTI-V, the horizontal displacement resulted quite difficult to be detected, either with cars (Marotta et al., 2015; Roca et al., 2011) or arrows (Bukowski et al., 2015; Morales et al., 2015) as stimuli.

More importantly, an executive vigilance decrement was found, which interestingly was observed as an increment in response bias, rather than as a loss in sensitivity. Recently, Thomson et al. (2016) reviewed several studies in which a floor effect in the FAs might be leading to an incorrect analysis of the vigilance decrement. While the decrement is usually interpreted as a loss in sensitivity, the FAs floor effect could be masking an increment in the response bias across time. Thus, Thomson et al. (2016) developed a novel vigilance paradigm and conducted an experiment aiming to increase the FAs. Although observing a FAs rate of ∼30% in the first task period, no increment of FAs across time was found, necessary to reveal some loss in sensitivity (Thomson et al., 2016). Instead, and in line with our findings in the first experiment of this paper, both hits and FAs decreased over time, therefore demonstrating an increment in response bias.

Finally, regarding the analysis of the ANTI trials, we did not anticipate several differences found between the two task versions. In

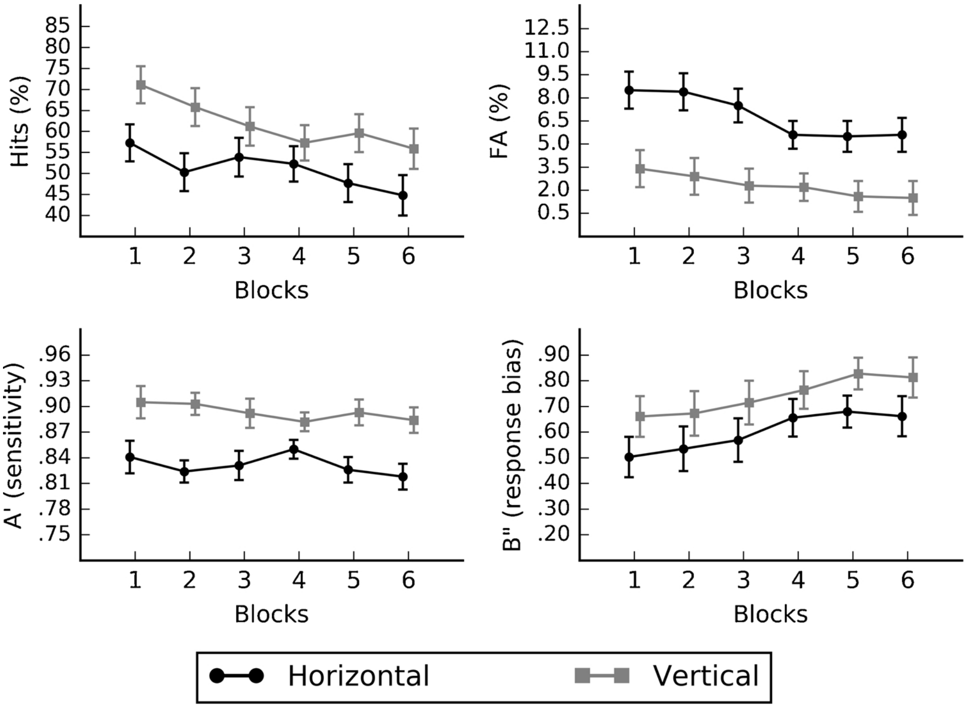

Fig. 2. Executive Vigilance decrement in ANTI-V task versions. Performance across time on task in Hits (top left graph), FA (top right graph), A' sensitivity (bottom left graph), and B" response bias (bottom right graph). Bars represents SE.

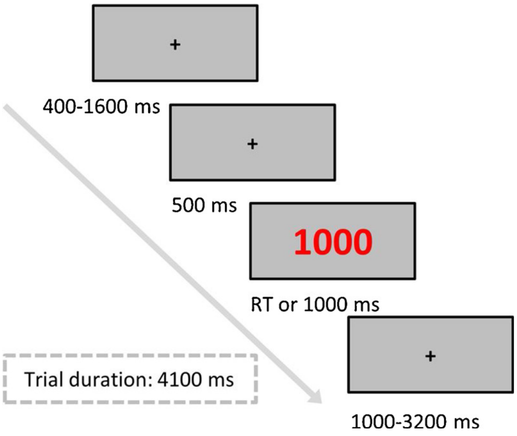

Fig. 3. Stimuli sequence of the AV trials in the ANTI-Vea. Responses were allowed until 2000 ms since the down counter presentation.

general, participants had faster and more accurate responses in the vertical than in the horizontal version. In addition, the usual cueing effect (valid < no cue < invalid; see, for example, Merritt et al., 2007; Posner, 2014) was found in both tasks with RT data, but only in the vertical version of the task with accuracy data. Moreover, regarding the executive control, the interference effect seems to be reduced to the half or less in the vertical version, as compared to previous versions of the task, like the ANT (Fan et al., 2002), the ANTI (Callejas et al., 2004), and the ANTI-V (Morales et al., 2015; Roca et al., 2011).

In summary, the results obtained seem to support that the vertical version of the task is easier to perform than the horizontal one, and that it is a valid task to observe the vigilance decrement. In the following experiment, we aim at replicating these findings and, additionally, we will include an arousal vigilance measure. The proposed new task may result suitable to analyze separately the two vigilance components, executive and arousal, and their decrement over time.

6. Experiment #2: Adding an arousal vigilance measure

The main goal of this experiment was to design a task (ANTI-Vea) that could measure simultaneously the typical attentional functions, together with the two components of vigilance: executive vigilance (i.e., response control to discriminate infrequent from frequent events), and arousal vigilance (i.e., sustaining a tonic arousal level to achieve a fast reaction). Regarding the executive vigilance, we expected to replicate the decrement as an increment in the response bias, and not as a sensitivity loss (Thomson et al., 2016). In addition, we also designed our new task to be suitable for observing the decrement in arousal vigilance, probably as a progressive increment in both the mean and the variability of the reaction time.

Additionally, we expected to replicate the findings observed in Experiment #1 between the horizontal and vertical task versions on executive vigilance and on the interference effect. Therefore, two different versions of the new ANTI-Vea task were compared, like in Experiment #1 (horizontal and vertical). We expected executive vigilance trials to be again easier to complete for the vertical than the horizontal version of the task. However, probably the inclusion of the arousal vigilance measure could make the whole task more difficult, because the attentional set needed to resolve three tasks simultaneously should be larger (i.e., three different instructions to comply with, instead of two). As a result, some differences between the two task versions of the ANTI-Vea could be even larger (e.g., overall RT and the percentage of errors in the ANTI trials, and the interference effects) than in Experiment #1.

7. Materials and methods

7.1. Participants

Participants ($n = 80$; 40 females) were students or recently graduated at the National University of Córdoba, Argentina (age: between 18 and 40, $M = 25.17$, $SD = 6.05$; education years: $M = 14.53$; $SD = 1.98$). They were randomly assigned to one of two groups, according to the task version administered (horizontal or vertical). The groups did not differ in age [t (78) = -0.44, $p = .660$], or education years [t (78) = 0.73, $p = .466$].

7.2. Apparatus and stimuli

Stimuli were the same as in Experiment #1. In addition, a red millisecond down counter (~110 px height each number) was intermittently presented at fixation, to obtain an arousal vigilance measure.

7.3. Procedure and design

In the ANTI-Vea task, there are three different types of trials: ANTI, EV, and arousal vigilance (AV). For the ANTI and the EV trials (respectively, 60% and 20% of the trials), the stimuli sequence and timing, response keys, and design, were the same as in Experiment #1 (see Fig. 1). In the AV trials (20%, see Fig. 3), no tone, visual cue, or arrows were presented. These trials started as the ANTI and EV trials, and then the fixation point remained fixed in the screen for 500 ms (i.e., the same duration as for the tone plus the visual cue signals in the ANTI and EV trials). Next, a red millisecond counter appeared in the center of the screen, starting at 1000 and going down to zero. Participants were asked to stop the counter as fast as they could, by pressing any key of the keyboard.

Before starting the experimental task, participants performed several practice blocks with visual feedback. First, instructions to resolve the ANTI trials were given, with a practice block of 16 ANTI trials. Next, instructions about the EV trials were presented, with a practice block of 32 randomized trials (16 ANTI and 16 EV). Then, instructions for the AV trials were given, followed with a practice block of 48 randomized trials (16 ANTI, 16 EV, 16 AV). Finally, participants performed a last practice block of 40 randomized trials (24 ANTI, 8 EV and 8 AV; half of one experimental block), without visual feedback. At this point, if participants still had any doubt, they could ask questions or perform again the last practice block. Otherwise, they continued with the experimental section of the task, that included six blocks of 80 randomized trials (48 ANTI, 16 EV and 16 AV per block), with no pause and no visual feedback. The factorial design of the ANTI trials and the selection procedure for EV trials was the same as in Experiment #1.

7.4. Data analysis

The data from six participants with more than 25% of errors in the ANTI trials were excluded. Then, for the ANTI and the EV trials, the analyses conducted were the same as in Experiment #1. For RT analyses, incorrect responses (9.79%) and with RT smaller than 200 ms and higher than 1500 ms (2.40%) were excluded.

For the AV trials, the mean and SD of RT were obtained per block. Note that in the PVT (Lim and Dinges, 2008), one typical measure is the analysis of lapses (i.e., late responses to the millisecond down counter), generally considered as a response time equal to or larger than 500 ms (Basner and Dinges, 2011). The mean (and median) RT in the PVT is usually around 250 ms when the lapses threshold is stablished at 500 ms (Basner et al., 2011; Blatter et al., 2006; Drummond et al., 2005; Lee et al., 2010; Lim and Dinges, 2008; Loh et al., 2004). However, in the ANTI-Vea task, it was observed a higher mean and median RT (close to 480 ms), probably due to the inclusion of the ANTI and the EV trials together with the millisecond down counter. Therefore, the lapses in

Table 2
Mean and standard deviation (in parentheses) for correct RT and accuracy (percentage of errors) of Experiment 2 for each condition of the ANTI factorial design in the horizontal and vertical ANTI-Vea versions: Warning signal (No tone/Tone) × Visual cue (Invalid/No cue/Valid) × Congruency (Congruent/Incongruent).

			No tone			Tone		
			Invalid	No cue	Valid	Invalid	No cue	Valid
Reaction Time								
	Horizontal	Congruent	702 (132)	718 (122)	677 (122)	678 (119)	663 (127)	656 (131)
		Incongruent	805 (119)	791 (147)	766 (127)	807 (142)	759 (141)	763 (137)
	Vertical	Congruent	648 (88)	650 (93)	628 (94)	641 (87)	618 (94)	597 (86)
		Incongruent	685 (81)	686 (90)	661 (93)	695 (90)	645 (87)	626 (77)
Accuracy								
	Horizontal	Congruent	6.6 (6.5)	6.3 (5.3)	6.9 (7.4)	3.2 (4.2)	4.4 (5.2)	5.7 (7.3)
		Incongruent	16.2 (11.5)	15.4 (8.3)	15.4 (9.7)	13.3 (9.7)	13.7 (10.8)	15.7 (10.6)
	Vertical	Congruent	7.3 (7.6)	6.3 (6.6)	9.1 (6.8)	5.9 (7.0)	4.2 (5.2)	6.8 (6.7)
		Incongruent	6.1 (8.5)	7.1 (6.6)	7.1 (7.0)	4.3 (4.4)	3.5 (4.4)	7.1 (6.8)

the ANTI-Vea task were defined as responses larger than 600 ms. This criterion was selected after comparing the percentage of lapses across blocks with four different thresholds: > 500 ms, > 600 ms, > mean + 1 SD of RT by participant, > mean + 1 SD of RT by group. Finally, three repeated measures ANOVAs were separately conducted including task Block (6 levels) as a within-participants factor, and Task Version (Horizontal/Vertical) as a between-participants factor, one for each dependent variable: mean RT, SD of RT, and lapses percentage.

8. Results

8.1. Phasic alertness, orienting and executive control

Mean RT and accuracy for the ANTI trials are shown in Table 2.

8.1.1. Reaction time

Significant main effects were found again for the three within-participants factors: Warning signal [F (1, 72) = 55.49, $p < .001$, $\eta_p^2 = .44$], Visual cue [F (2, 144) = 64.49, $p < .001$, $\eta_p^2 = .47$], and Congruency [F (1, 72) = 231.20, $p < .001$, $\eta_p^2 = .76$]. The main effect Task Version was also significant [F (1, 72) = 11.85, $p < .001$, $\eta_p^2 = .14$], with lower RT for the Vertical (M = 648 ms; SD = 82) than for the Horizontal version (M = 729 ms; SD = 123).

As in the previous experiment, and it is usually found with the ANTI and ANTI-V tasks, the Warning signal × Visual cue [F (2, 144) = 20.09, $p < .001$, $\eta_p^2 = .22$], Warning signal × Congruency [F (1, 72) = 6.42, $p = .013$, $\eta_p^2 = .08$], and Visual cue × Congruency [F (2, 144) = 10.94, $p < .001$, $\eta_p^2 = .13$] interactions were significant. The three-way within-participants factors interaction did not reach significance [F (2, 144) = 0.97, $p = .381$, $\eta_p^2 = .01$].

Task Version modulated Congruency [F (1, 72) = 50.51, $p < .001$, $\eta_p^2 = .41$]: a much reduced interference effect was again observed in the Vertical (36 ms), as compared to the Horizontal version (100 ms). Finally, an interaction was found between Warning signal, Visual cue, and Task Version [F (2, 144) = 5.36, $p = .005$, $\eta_p^2 = .07$]. In the Vertical version, the warning tone increased the facilitation effect of cueing (valid = 612 ms; no cue = 631 ms; invalid = 668 ms) with respect to the absent tone condition (valid = 645 ms; no cue = 668 ms; invalid = 667 ms). Instead, in the Horizontal version, the cueing effect was similar for the tone (valid = 709 ms; no cue = 711 ms; invalid = 742 ms) and no tone trials (valid = 721 ms; no cue = 754 ms; invalid = 754 ms).

8.1.2. Accuracy (% of errors)

Significant main effects were observed for all the within-participants factors: Warning signal [F (1, 72) = 16.43, $p < .001$, $\eta_p^2 = .19$], Visual cue [F (2, 144) = 8.27, $p < .001$, $\eta_p^2 = .10$], and Congruency [F (1, 72) = 46.60, $p < .001$, $\eta_p^2 = .39$]. The Task Version effect was also significant [F (1, 72) = 12.71, $p < .001$, $\eta_p^2 = .15$]. As in Experiment#1, responses were more accurate in the Vertical (M = 6.24%; SD = 4.15) than in the Horizontal version (M = 10.23%; SD = 5.42).

Only the Congruency × Task Version interaction reached significance [F (1, 72) = 63.08, $p < .001$, $\eta_p^2 = .47$]. As with RT, a reduction in the interference effect was observed in the Vertical (- 0.71%) as compared to the Horizontal version (9.44%).

8.2. Executive vigilance decrement

8.2.1. Reaction time

As in Experiment #1, mean RT [F (5, 350) = 0.75, $p = .583$, $\eta_p^2 = .01$] and the SD of RT [F (5, 345) = 0.62, $p = .683$, $\eta_p^2 = .01$] did not change significantly across Blocks. The main effect of Task Version was only found for mean RT [F (1, 70) = 10.55, $p = .002$, $\eta_p^2 = .13$], with smaller RT for the Vertical (M = 776 ms; SD = 80) than for the Horizontal version (M = 863 ms; SD = 128). No significant interactions were found.

8.2.2. Hits and false alarms

A significant main effect of Block was observed for both Hits [F (5, 360) = 3.94, $p = .001$, $\eta_p^2 = .05$] and FAs [F (5, 360) = 2.46, $p = .033$, $\eta_p^2 = .03$]. Planned comparisons confirmed a linear decrement for both Hits [F (1, 72) = 10.87, $p = .001$] and FAs [F (1, 72) = 4.42, $p = .039$], as observed in Fig. 4.

Additionally, the main effect of Task Version was also significant for both Hits [F (1, 72) = 12.64, $p < .001$, $\eta_p^2 = .15$] and FAs [F (1, 72) = 14.43, $p < .001$, $\eta_p^2 = .17$]. Hit rate was higher in the Vertical (M = 74.89%; SD = 17.85) than in the Horizontal version (M = 58.62%; SD = 21.43), and FAs rate was smaller in the Vertical (M = 4.24%; SD = 3.03) than in the Horizontal version (M = 7.97%; SD = 5.18). No significant interactions were found.

8.2.3. Sensitivity and response bias

The main effect of Block was only found for Response Bias (B") [F (5, 360) = 3.17, $p = .008$, $\eta_p^2 = .04$], but not for Sensitivity (A') [F (5, 360) = 1.66, $p = .143$, $\eta_p^2 = .02$]. As can be observed in Fig. 4, Response Bias increased linearly with time on task [F (1, 72) = 1.72, $p = .006$]. In addition, planned comparisons revealed that the linear component of Sensitivity for each task version did not reach significance: Vertical [F (1, 72) = 3.08, $p = .083$] and Horizontal version [F (1, 72) = 0.73, $p = .395$].

In contrast, the main effect of the Task Version was only found for Sensitivity [F (1, 72) = 26.33, $p < .001$, $\eta_p^2 = .27$], with a higher discrimination in the Vertical (A' = .92) than in the Horizontal version (A' = .85). The Task version effect was not observed for Response Bias [F (1, 72) = 0.06, $p = .800$, $\eta_p^2 = .01$] (Horizontal B" = .48; Vertical

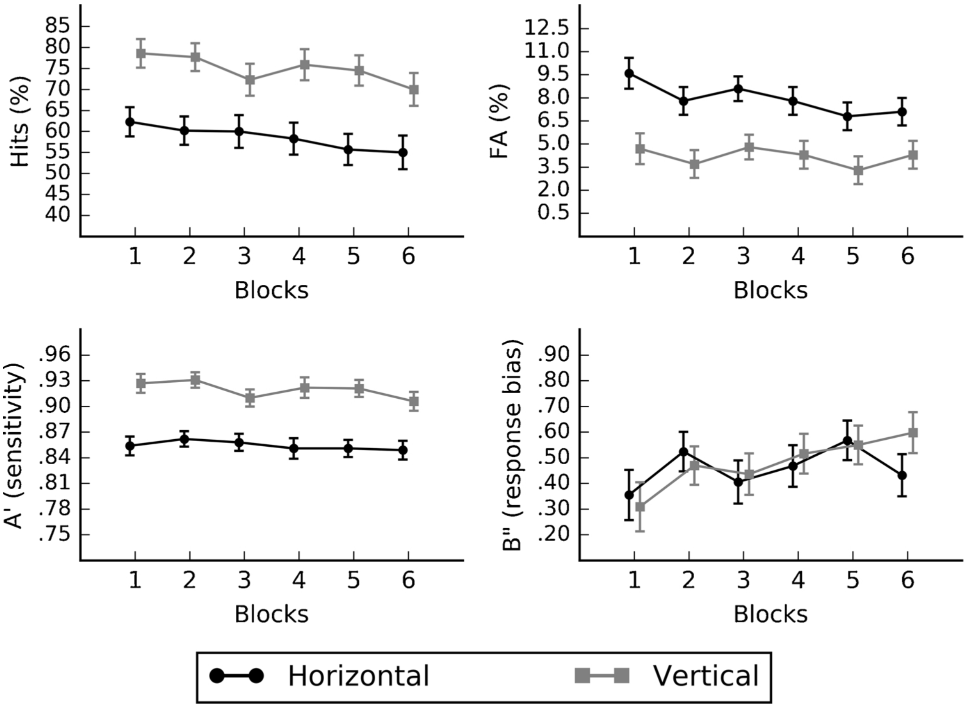

Fig. 4. Executive Vigilance decrement in ANTI-Vea task versions. Performance across time on task in Hits (top left graph), FA (top right graph), A' sensitivity (bottom left graph), and B" response bias (bottom right graph). Bars represents SE.

B" = .55). No significant interactions were found.

Because the increment in Response Bias seems to be linearly different in each task version (see Fig. 4), planned comparisons were performed to test the polynomial linear component. The contrast between both task versions was not significant [F (1, 72) = 1.99, p = .162]. However, when the linear component of Blocks was analyzed considering one single task version, the B" linear increment was significant for the Vertical [F (1, 72) = 9.08, p = .003], but not for the Horizontal [F (1, 72) = 0.92, p = .339] version.

8.3. Arousal vigilance decrement

8.3.1. Mean and SD of reaction time, and lapses percentage

Significant main effects of Block were found for mean RT [F (5, 360) = 3.61, p = .003, η_p^2 = .05], the SD of RT [F (5, 360) = 6.79, $p < .001$, η_p^2 = .09], and Lapses percentage [F (5, 360) = 5.11, $p < .001$, η_p^2 = .07]. All these variables increased linearly with time on task, as it is shown in Fig. 5: mean RT [F (1, 72) = 8.50, p = .004], the SD of RT [F (1, 72) = 16.79, $p < .001$], and Lapses percentage [F (1, 72) = 13.03, $p < .001$]. Task version main effect was not observed either for mean RT (Horizontal overall = 484 ms; Vertical overall = 479 ms), the SD of RT (Horizontal overall = 83; Vertical overall = 81) or Lapses percentage (Horizontal overall = 9.83%; Vertical overall = 7.70%). No significant interactions were found.

9. Discussion

The ANTI-Vea task developed in Experiment #2 aimed to assess the executive and arousal components of vigilance separately, while also measuring the classic attentional functions. With this novel task, we expected to observe the decrement in the two components of vigilance in a single session. Additionally, we looked to replicate the findings of Experiment #1, and thus observe that the vertical version was easier to complete than the horizontal one. Last but not least, we expected that the inclusion of the arousal vigilance measure would not alter the assessment of the classic attentional functions (Callejas et al., 2004).

Regarding the arousal vigilance measure, no differences were observed between the vertical and horizontal task versions in the mean,

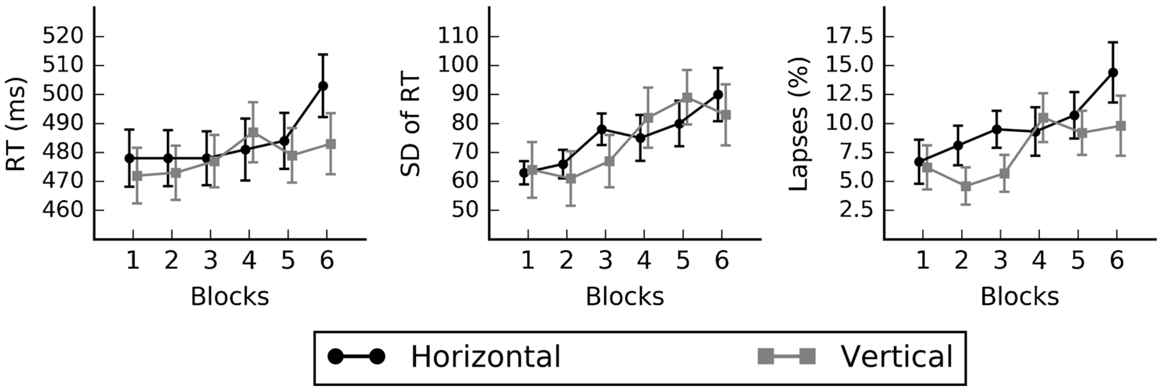

Fig. 5. Arousal Vigilance decrement in ANTI-Vea task versions. Performance across time on task in mean RT (left graph), SD of RT (center graph) and Lapses percentage (right graph) for each ANTI-Vea task version. Bars errors represents SE.

the SD of RT, or the percentage of lapses. It should be noted that the overall RT found with the ANTI-Vea was ∼200 ms slower than in several studies with the PVT task (Basner et al., 2011; Blatter et al., 2006; Drummond et al., 2005; Lee et al., 2010; Lim and Dinges, 2008; Loh et al., 2004). In the PVT, the inter-stimuli-interval (ISI) is set between 2 to 10 s (Basner and Dinges, 2011), while in the ANTI-Vea the ISI is ∼16 s on average (i.e., every 4 trials). Moreover, and perhaps more importantly, during the ISI in the ANTI-Vea, participants may receive several visual and auditory signals, whiles performing the flanker and executive vigilance tasks. Therefore, it could be possible that increasing the task demands and the number of stimuli between two down counter may explain the larger overall RT observed in the arousal vigilance component. Maybe the ANTI-Vea would be useful to study, from a new perspective, the decrement of arousal vigilance under conditions of sleep loss (Basner et al., 2013; Krause et al., 2017), together with executive vigilance and executive control (Perrier et al., 2015; Roca et al., 2012).

For the executive vigilance, the vertical version of the ANTI-Vea task did not produce a ceiling effect in hits (overall ∼75%) neither a floor effect in FAs (overall ∼4%), as other simple and monotone vigilance tasks usually do (for a review, see Thomson et al. (2016, 2015)). Indeed, the hit rate reported in the current study is higher than the usual results in previous ANTI-V studies (45%–60%). Most important, as both hits and FAs showed a decrement across time, the progressive increment in response bias was replicated (being more pronounced in the vertical than in the horizontal version), like in Experiment #1.

Finally, the results obtained in the second experiment seem to confirm that the displacement of the infrequent target in one dimension or the other impacts also the resolution of the embedded flanker task. In the vertical version, responses were faster and more accurate in general, and a reduced interference effect was found, as in Experiment #1. In addition, the warning signal increased the cueing facilitation effect only in the vertical version, an interaction that has been observed previously with other attentional networks tasks (Callejas et al., 2005; Roca et al., 2013a, 2011).

10. General discussion

The current study aimed to develop a new version of the attentional network test, the ANTI-Vea, to assess in a single session the classic attentional functions, together with the executive and arousal vigilance components. The observed pattern of results seems to show that the task provided the expected measures. We tested the new attentional task on young adults between 18 and 40 years, and replicated the main findings across different countries. The new task provides the usual measures of phasic alertness, orienting and executive control, and new measures (i.e., vigilance decrements) of both arousal and executive vigilance. Furthermore, the new task seems to be easier to perform, which makes it more suitable to test attentional performance in different populations as, for example, in the elderly, where the functioning of the executive control and alertness networks might be compromised (Williams et al., 2016; Zhou et al., 2011). Thus, we expect the task developed here to be useful for future studies aiming to understand the development of the attentional networks across adulthood, something that could not be achieved with the previous version of the ANTI-V (Moratal et al., 2015).

Importantly, the vertical version of the task proposed here resulted suitable to observe the executive vigilance decrement, as an increment in response bias. Several vigilance studies have observed this decrement as a loss in sensitivity, explaining such phenomenon as a depletion of attentional resources (for a review, see Warm et al. (2008)). Moreover, it has been proposed that requiring a higher cognitive effort, or increasing the working memory load during the vigilance activity, might produce a larger decrement (Head and Helton, 2014; Helton and Russell, 2011). However, with the ANTI-Vea task, participants resolved three tasks simultaneously with a high cognitive load, and sensitivity did not change across time. In contrast, the executive vigilance decrement was observed as an increment in the response bias, consistently with Thomson et al. (2016) (see Section 5).

It should be noted that recently, the findings by Thomson et al. (2016) received several comments by Fraulini et al. (2017). These authors objected the way Thomson et al. (2016) analyzed SDT metrics, as they dissociated three stimuli distributions (signal, noise, and ‘lures’) in a novel vigilance paradigm. Moreover, Fraulini et al. (2017) pointed out that data was collected online, without controlling the experimental context. Nevertheless, the experiments conducted in the present study do not share these potential flaws identified by Fraulini et al. (2017), still supporting the idea that executive vigilance decrement is best interpreted as an increment in response bias rather than a loss in sensitivity.

On the other hand, with the ANTI-Vea we could also analyze the arousal vigilance decrement. The duration of the ANTI-Vea (33 min approximately) is larger than the PVT, generally about 10 min (Basner and Dinges, 2011). The PVT has been widely used to analyze the arousal vigilance decrement under conditions of total (Lamond et al., 2008) or partial (Basner et al., 2011) sleep deprivation. In these sleep loss studies, the PVT is usually administered every one or two hours, and the decrement is analyzed across the total time of evaluation. For example, using the PVT, Loh et al. (2004) observed a linear decrement higher than 50 ms just in one night of sustained wakefulness (from 11 p. m. to 6 a. m.). Within the first two hours of evaluation, participants in the latter study showed a decrement close to 20 ms, similar to the results obtained here with the ANTI-Vea task.

With the vertical version of the ANTI-Vea task, we observed a reduced hit rate (∼75%) for EV, and a larger overall RT (479 ms) for AV, in comparison to the performance usually observed with the SART and PVT tasks respectively. It could be possible that the increment on task demands (i.e., to solve three tasks simultaneously, instead of only one) might modulate performance on the vigilance components. To address this issue, we conducted another study in our laboratory (Luna et al., Unpublished results), in which participants responded to either the executive vigilance task alone (i.e., as in the SART) or the arousal vigilance alone (i.e., as in the PVT), ignoring any other stimuli of the ANTI-Vea, which were nevertheless presented. When participants only responded to the executive vigilance task, we found the classic ceiling effect on hits (∼90%), with a more pronounced decrement (2.33% per block) than with the vertical version of the ANTI-Vea (1.40% per block). When participants only responded to the arousal vigilance task, we found a faster overall RT (391 ms), together with a three times larger decrement (7.65 ms increment per block), than in the current research (2.50 ms per block).

Whilst in the present study our main goal was to measure separately the executive and arousal vigilance components using a single task, further studies will be necessary to analyze if these components can be dissociated from one another. Previously, Sarter et al. (2001) have proposed that vigilance may be conceived as separated from the arousal components of attention. They described vigilance as a behavioral function to detect unusual targets, which is supported by a top-down functioning of the cholinergic neural system. In contrast, the arousal component of attention may not involve a specific behavioral responsiveness, but it could be necessary for the development of vigilance across time by the bottom-up innervations of the noradrenergic system. In the present study, we describe the behavioral pattern for each component, including the type and size of the associated performance decrement. Future studies linking neuroimaging and behavioral data may contribute to the analysis of the independence of these vigilance components (Posner, 2012; Posner et al., 2006).

Finally, although we expected no significant differences in the measurement of the classic attentional functions, in both experiments we found a much reduced interference effect in the vertical version of the task, as compared to the horizontal version. We consider that this modulation of the interference effect cannot be entirely explained by the direction of the infrequent target displacement. Previous studies with the 'lateralized ANT task' reported similar interference effects with stimuli presented vertically (i.e., a column of arrows in one or another side of the screen), and stimuli presented horizontally (Asanowicz and Marzecová, 2017; Greene et al., 2008). Thus, we decided to conduct a new study specifically to address this issue (for a reference of the project in Open Science Framework, see https://osf.io/h4tk7). We hypothesized that staying vigilant to the vertical displacement of the target might help to segregate this stimuli from the surrounding arrows in the embedded flanker task, in contrast to the horizontal displacement. Thus, in this study we presented the same stimuli as the standard task used in Experiment 2 of the current study. However, participants had to either respond to only the flanker task (ignoring any other stimuli), or at the same attending and responding with the space bar to the vertical vs. the horizontal displacement of the central arrow. Results showed the typical interference effect (~50 ms) when just solving the flanker task, a smaller effect (~35 ms) when attempting to detect at the same time the vertical displacement, and a larger interference (~100 ms) when attending to the horizontal infrequent displacement (Luna et al., Unpublished results).

In any case, the results obtained here seem to support the idea that the vertical version of the ANTI-Vea task is more appropriate to assess the classic attentional functions. This version shows the typical interactions previously observed in the ANTI task (Callejas et al., 2005, 2004). Moreover, the reduction found in the interference effect has an additional advantage. The indexes of the three classic attentional functions are of a similar size, around 40 ms each, with the ANTI-Vea (vertical version), whereas the index of executive control is at least twice the size of the other indexes in the other versions of the task: the horizontal version, the ANT (Fan et al., 2002), and the ANTI (Callejas et al., 2004).

11. Conclusions

The current study presents a new attentional networks test (ANTI-Vea) developed for measuring phasic alertness, orienting and executive control, and their interactions, while assessing both executive and arousal components of vigilance. The executive vigilance decrement was found as an increment in response bias towards a more conservative criterion. On the other hand, the arousal vigilance decrement was observed as a progressive increment of both the mean and the variability of RT, and percentage of lapses. In addition, the vertical version of the task proposed here results easier to perform than the previous horizontal version developed by Roca et al. (2011), as indicated by faster overall RT and fewer errors, together with a great reduction in the interference effect. Therefore, it is expected the ANTI-Vea task would be more useful for studying the functioning of the attentional networks in different populations of interest, such as clinical patients and older adults.

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Declaration of interest

None.

Data set

Luna et al. (2017). DOI: https://doi.org/10.17632/bzd778pfkg.1.

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