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Un-experienced vs. Experienced drivers. Limitations of Human Attention. An analysis of their THREE ATTENTIONAL NETWORKS.

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Abstract

This paper reports on a study of the Three Attentional Networks (Orienting, Executive Function and Alerting) and the role that two variables (age and driving experience) play in their functioning. The ANTI task (Attentional Network Test-Interaction) developed by Callejas, Lupianez and Tudela (2004) was used. In Callejas' task, a cost and benefit paradigm was combined with a flanker task and an alerting signal. The task was performed by a group of young Non-experienced drivers and a group of Experienced drivers. The pattern of results from Non-experienced drivers was different from that of Experienced drivers. For Non-experienced drivers there was a functional difference in the three attentional networks. These interactions were significant for the Non-Experienced drivers: a.) The interaction effect between the Orienting and Alerting networks: the presence of the sound enhances Orienting Effect, b.) The interaction effect between the Congruency and Orienting networks: a greater Congruency effect when the participant viewed a cue in the location opposite to that of the target. c.) The interaction between Alertness and Congruency: alerting produces an inhibitory effect on the Executive Function. However, for Experienced drivers, smoother patterns of interaction were found among the three attentional networks. Further research should be done firstly to measure the functioning of the attentional networks in other complex tasks, more similar to driving, secondly to clarify that the difference found is not only a function of age. . .

Keywords:
Attentional networks, Exogenous orienting, Flanker task, Phasic alerting, Age, Driving, Driving Experience.

Acknowledgements

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An introduction to the three attentional networks

By modifying Fan's ANT task (Fan, McCandliss, Sommer, Raz and Posner, (2002), Callejas, Lupianez and Tudela (2004) created a task that could measure the interactions among the three attentional networks and the effect of each of them on the other two networks. These networks have now been defined in anatomical and functional terms. The task was designed to evaluate orienting, executive attention and alerting, within a single 30-min testing session that could be easily performed by participants of all ages. To discover the effect of the Orienting Network, the Cueing variable was manipulated at three levels; valid (cued trials), invalid (uncued trials) and neutral trials (with no cue). The Executive Control function was studied by analysing the congruency effect. The target stimulus consisted of an arrow pointing either to the right or the left, flanked by two arrows on each side that could be pointing in the same direction as the target (congruent trials) or in the opposite direction (incongruent trials). Finally, the task of Callejas *et al.* (2004) introduced a variable (a short-duration high-frequency tone) to independently measure the alerting network.

In recent years, research on attention has involved three networks of anatomical areas that perform the functions of orienting, alerting and executive control. A correct functioning of the three attentional networks is essential to guarantee safe driving.

The Executive control network is thought to be active when the cognitive system faces situations that involve planning, making a decision, detecting and error, giving a novel response or overcoming habitual actions (Norman and Shallice, 1986). Tasks dealing with conflict, handling novelty, and detecting errors are used to measure Attentional Executive Control (Posner and DiGirolamo, 1996)

Orienting is manipulated by presenting a cue indicating where in space a person should attend, thereby providing a basis for the person to direct attention to the valid (cued) location either overtly by moving the eyes or covertly without any eye movement (Posner, 1980).

Functional magnetic resonance imaging studies have suggested that the Executive Control Network is located in the anterior areas of the frontal cortex (Posner and Fan, 2005); the alerting system has been associated with the frontal and parietal regions of the right hemisphere (Coull, Frith, Frackowiak and Grasby, 1996;

and Marrocco, Witte and Davidson, 1994); and the superior parietal lobe is associated with orienting following the presentation of a cue (Corbetta, Kincade, Ollinger, McAvoy and Shulman, 2000).

Two types of alertness have been described, based on the task used to measure them. Tonic alertness or vigilance refers to sustained activation over a period of time, whereas phasic alertness is related to the non-specific activation experience when a warning signal is presented prior to the target. Both types of alertness play a crucial role when driving. Vigilance is usually measured using tasks where participants have to attend to a location over a period of time and detect infrequent targets. Phasic alertness is studied by measuring the influence on reaction time (RT) to a signal hat only provides temporary information.

Age differences in the processing of the three attentional networks

Extensive cognitive and neuroimaging studies of these networks have been conducted in adults, mainly young students with a mean age of less than 30. However, Rueda, Fan, McCandliss, Halparin, Gruber, Lercari, and Posner (2004) demonstrated that the functioning of the three attentional networks varied according to age. They adapted the Attentional Network Test (ANT), Fan *et al*'s task (2002), to study the development of these networks during childhood. Reaction time and accuracy improved at each age interval and positive values were found for the average efficiency of each of the networks. Alertness showed evidence of change up to and beyond age 10, while conflict scores appeared stable after age 7 and orienting scores did not change in the age range studied. The efficiency of each of the networks may also vary as a function of other variables such as driving experience.

Attention & driving

Driving is an example of an everyday task in which survival relies on attention and, particularly, on visual attention (Recarte and Nunes, 2008). Distraction is an explanatory concept for traffic accidents. It can be considered as attentional inefficiency: a dysfunction in information processing leading to increased risk and human error.

Current studies have investigated the role that attention plays in driving from different points of view: Nelson, Tuttle and Backs (2007) examined the relationship between attention abilities (selective, scanning, switching, sustaining and divided) assessed with a computer-based test battery and a driving simulator. According to their results, the speed, visual search and divided attention components seemed to be significant predictors more often than did the sustained, switching, orienting, and selective components. The ultimate aim of this study was to find out whether determining a person's attention profile would provide information about their driving and, therefore, be useful for examining driving skills, for instance, in impaired populations.

In addition, Lee, Lee, and Ng Boyle (2007) investigated the effect of cognitive load on the guidance of visual attention. Previous studies have shown that cognitive load can undermine driving performance, particularly drivers' ability to detect safety-critical events. Cognitive load combined with the loss of exogenous cues, which can occur when the driver briefly glances away from the road, may be particularly detrimental. In their study, participants engaged in an auditory task while performing a change detection task. A change blindness paradigm was implemented to mask exogenous cues by periodically blanking the screen in a driving simulator while a change occurred. Performance measures included participants' sensitivity to vehicle changes and confidence in detecting them. They concluded that cognitive load uniformly diminished participants' sensitivity and confidence, independent of safety relevance or lack of exogenous cues. Periodic blanking, which simulated glances away from the road, undermined change detection to a greater degree than did cognitive load; however, drivers' confidence in their ability to detect changes was diminished to a greater extent by cognitive load than by periodic blanking. Therefore, according to Lee *et al*'s study, cognitive load and short glances away from the road are cumulative in their tendency to increase the likelihood of drivers missing safety-critical events. The authors try to apply the result to the real traffic environment and highlight the need to consider the combined consequences of cognitive load and brief glances away from the road when designing new in-vehicle devices as well as the need to provide drivers with better feedback regarding these consequences.

Recently, Weaver, Bédard, McAuliffe and Parkkari (2008, in press) use the Attentional Network Test to predict driving test scores. They define driving as a complex multifactorial task that taps underlying mechanism of cognition and attention. Therefore, many test of cognition of attention are significantly associated with driving outcomes. They demonstrate that the ANT has very good concurrent validity with the Useful Field of View (UFOW), and that is comparable to UFOV in its ability to predict road test scores for a simulated drive. To our Knowledge only this work (Weaver *et al.,* 2008 in press) and the current research are using the Attention Network Test (ANT) in driving research.

Driving experience & Attention while driving

Non-experienced drivers are at disproportionate risk of involvement in a crash. As they gain experience, their road accident liability decreases. According to Underwood, Crundall and Chapman (2008) this can be attributed in part to changes in the distribution of attention. As well as knowing better where to look, they are also less distracted by events that are unrelated to the task of driving.

Underwood, Chapman, Brocklehurst, Underwood, and Crundall (2003) explored the role that driving experience plays in visual attention while driving. They found differences in sequences of fixations between Non-experienced and Experienced drivers on three types of road (rural, suburban and dual-carriageway), with Experienced drivers showing greater sensitivity overall, and with some stereotypical transitions in the visual attention of the non-experienced. A number of individual sequences were identified, including a road preview pattern (alternating fixations between near and distant views of the road ahead), and patterns involving mirror inspections that varied according to the road type.

Current research

The main goal of this study was to find out whether differences in the functioning of the three attentional networks could be found between Non-experienced and Experienced drivers. Determining the driver's attention profile would provide information about her/his driving and therefore be useful for examining driving skills, for instance in impaired populations or for deciding on training methods.

Method

Participants

Twenty participants, students and staff, from the University of Nottingham took part in this experiment for a remuneration of £3. The 10 Non-Experienced drivers were learning to drive, receiving practice lessons and taking their driving exam for obtaining the driving licence. The 10 Experienced drivers had more than 8 years of driving experience. They all reported normal or corrected-to-normal vision and were unaware of the purpose of the experiment. The ages of the non-experienced drivers group ranged from 18 to 28. Those of the Experienced drivers group ranged from 24 to 43. This experiment was performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki. All the participants gave their informed consent prior to their inclusion in the study.

Apparatus

A Pentium III computer with a 15-inch colour screen monitor, running E-Prime software (Schneider *et al.* 2002) was used for programming, presentation of stimuli and timing operations. Responses were collected using the keyboard of the computer and the computer speakers were used to deliver an alerting signal.

Stimuli

The stimulus used for the orienting signal was an asterisk presented in the same location as the target (0.6° of visual angle above or below fixation point). For the alerting signal, a 2000 Hz and 50 ms sound was used. The target display was made up of a target arrow that could point either to the left or to the right and four flankers or arrows pointing either to the left or right. The length of the arrows was 0.55° and they were 0.06° away from each other.

Design

The experiment had a 3 (Visual Cue) X 2 (Congruency) X 2 (Auditory Signal) X (2) (Driving experience) factorial design.

The Visual Cue had three levels: neutral (no orienting cue was presented); valid trials (cued, an orienting cue was presented in the same location as the subsequent target); and invalid trials (uncued, the orienting cue was presented, but in the location opposite the target). The orienting cue was an asterisk presented for 100 ms above or below the fixation point in 2/3 of the trials.

Congruency had two levels: congruent trials (the target was flanked by arrows pointing in the same direction), and incongruent trials (the flanker arrows pointed in the opposite direction to that of the target).

The Auditory Signal had two levels: presence or absence of a 2000 Hz and 50 ms sound.

The number of trials per level of each variable was kept constant. This was especially important in the case of the Visual Cue, since a larger proportion of valid trials would have made the cue predictive of target location. The practice block had 24 trials and was followed by six blocks of 48 trials each, so there were eight trials per experimental condition in each block (24 trials per condition in the experiment). The trials were presented randomly within each block.

Procedure

Participants were seated approximately 60 cm from the computer screen, and were instructed to respond to the direction of the target stimulus by pressing one of two possible keys on the keyboard. Feedback regarding accuracy was given during the practice block but not during the experimental blocks. Participants could rest between blocks. The mapping of hand-response was always compatible (a right-pointing arrow was to be responded to with the right hand and a left-pointing arrow with the left hand). The task of the participants was to distinguish the direction of the target arrow. The sequence of events for each trial is shown in Figure 2.

The instructions given to the participants were as follows:

"A series of five arrows will be shown in the centre of the screen. Your task consists of saying what direction the central arrow is pointing. Please, to answer press the following keys: "c" if the central arrow points to the left <-- "m" if the central arrow points to the right --> . Sometimes the central arrow will point in a reverse direction to the other arrows. Please, remember: You should pay attention to the direction of the central arrow. For instance:

--> --> <-- --> -->

In this case you should press "c".

In the centre of the screen a small cross will appear " + " It is the fixation point. The arrows will appear above or below the fixation point. You should keep looking at the fixation point (" + ") during all the experiment."

Please Insert Figure 2 about here

A fixation point (a plus sign) of variable duration (400-1600 ms) was presented at the beginning of each trial. This was followed by the 50 ms alerting signal in only half the trials. After a 450 ms stimulus onset asynchrony (SOA), an orienting cue was presented for 100 ms above or below the fixation point in 2/3 of the trials. After another 500 ms SOA, the target and flankers were presented either in the same location or in the opposite one from the previous orienting cue. They were present on the screen for 1700 ms or until the participant gave a response. After the response was given, the fixation point that had been present during the whole trial was kept for a variable duration dependent on the duration of the initial fixation point and on the RT of the participant, so that every trial had the same duration (4450 ms). No stimulus was presented between trials. Consequently, participants did not know when one trial had finished and the next one had begun. This produced more uncertainty about when the signals were going to appear, which increased their informative value.

Results

Mean correct RTs after eliminating extreme values (RTs faster than 200 ms or slower than 1200 ms) were introduced into a 3 (Visual Cue) X 2 (Congruency) X 2 (Auditory Signal) X (2) (Driving Experience) ANOVA.

The 4 way interaction approached significance: $F(2, 36)=2,45$, $p = 0.1$). 3 (Orienting: Neutral, Valid vs. Unvalid) x 2 (Congruency: Congruent vs. Incongruent) x 2 (Alerting: No Auditory Signal vs. Auditory Signal) X (2) (Group: Non-experienced vs. Experienced).

Please Insert Figure 3Top & Figure 3 Bottom about here

Therefore 2 different ANOVAS were performed to discover the Orienting effect: One 2x2x2x(2) only for Valid (Cued) and Invalid (Uncued) trials and other 2x2x(2) only for Neutral (No cue) trials.

Firstly, the 2 (Orienting: Valid (Cued) vs. Invalid (Uncued)) X 2 (Congruency: Congruent vs. Incongruent) X 2 (Alerting: No Auditory Signal vs. Auditory Signal) X (2) (Group: Non-experienced vs. Experienced) ANOVA was analysed:

Non-experienced showed a greater Orienting effect than Experienced drivers, Non-experienced drivers had a greater difference between valid and invalid trials than Experienced drivers, $F(1,18)=5,49, p=0.0308$. The Group x Orienting x Alerting interaction approached significance $F(1, 18)=3,3970$, $p=0.08$. Non-experienced showed less interference in valid location trials, as shown in the standard task. Experienced drivers did not show this reduction ($F<1$). (See Figure 3-Top C, and 3-Bottom C).

The Alerting X Orienting interaction was marginally significant, $F(2,18)= 2,64$, $p<0.09$ for Non-experienced Drivers and under Alerting conditions: the effect of an Orienting Cue was greater than in those trials in which no alerting cue was presented. Therefore the cueing effect (difference between Valid (Cued) and Invalid-(Uncued) trials) was significantly greater in the trials with an alerting stimulus than in those where the alerting tone was not presented.

The Group x Congruency X Alerting interaction was significant, $F(1, 18)=5,04$, $p= 0,0375$. Non-experienced showed the expected interaction: Congruency and Alerting ($p=.006$). Experienced drivers did not show this ($F<1$) = the same amount of interference in the absence of the tone (i.e. without alerting) as in its presence (i.e. under alerting). (See Figure 3-Top B, and 3-Bottom B).

The Congruency X Alerting interaction was significant for Non-experienced drivers, $F(1,9)= 13,69$, $p<0.004$: They showed a greater congruency effect - difference between congruent and incongruent trials - when an alerting sound was present compared with those trials when it was absent. That is, they showed an increase in the RT for incongruent trials, those in which the flankers pointed in the opposite direction to that of the target. Therefore, it is true that for the group of Non-experienced drivers, the Alerting Network produces an inhibitory effect on the Executive Function Network to enhance fast responses to sensory input in order to detect an infrequent target and prevent the system from focusing on feelings or thoughts or on further processing of the stimulus.

The Congruency X Orienting interaction was significant, $F(2,18)=3,71$, $p<0.04$. A greater Congruency effect was found when the participant viewed a cue in the location opposite to that of the target than in conditions where the cue was either absent or present in the same location as the target. (See Figure 3-Top A, and 3-Bottom A)

For the group of Non-experienced drivers, a greater Congruency effect was found when the participant viewed a cue in the location opposite to that of the target. In valid trials, the asterisk appeared in exactly the same position as the target arrow, thus helping focus attention and making it easier for the participant to ignore the incongruent flankers.

Secondly, a 2x2x(2) mixed ANOVA on No-Cue trials was analysed in order to explore the Alertness effect: 2 (Alerting: No Auditory Signal vs. Auditory Signal) x 2 (Congruency: Congruent vs. Incongruent) x 2 (Group: Non-experienced vs. Experienced).

Here the expected main effect of each variable was significant: Alerting, F(1, 18)=90.99, p=,0001; Congruency F(1, 18)=36,73, p=,0001 and Group F(1, 18)=7,61, p=,012. In addition, the Congruency X Alerting interaction was significant, F(1, 18)=, 23,30, p=,0001. None of the other interaction effects differed from one experience group to the other.

Discussion

It can be said that for Non-experienced drivers, Callejas *et al*'s (2004) results were replicated. However, for Experienced drivers, smoother patterns of interaction between the three attentional networks were found.

The main findings for Non-experienced drivers from this study and from that of Callejas *et al.* (2004) can be summarised as:

- The interaction effect between the Orienting and Alerting networks: the effect of an Orienting Cue was greater under Alerting conditions than in those trials in which no alerting sound was presented.
- The interaction effect between the Congruency and Orienting networks: a greater Congruency effect when the participant viewed a cue in the location opposite to that of the target. When the asterisk

appeared in the same position as the target arrow, it helped focus the attention.

- The interaction between Alertness and Congruency: alerting produces an inhibitory effect on the Executive Function, enhancing fast responses to sensory input in order to detect an infrequent target and prevent the system from focusing on feelings or thoughts or on further processing of the stimulus.

Different pattern of results between Non-experienced and Experienced drivers: there was a functional difference in the three attentional networks for Non-experienced drivers. However, smoother patterns of interaction were found among the three attentional networks for Experienced drivers.

Further research should be done to measure the functioning of the attentional networks in other complex tasks similar to driving. It should explore the interesting interactions among the three attentional networks. These seem to vary according to driving experience, confirming the pattern found in the laboratory task, of stronger interactions for Non-experienced drivers. This could help us clarify that the difference found is not only a function of age.

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Table Captions

Table 1. Mean RT (ms) and percentage of errors (between parentheses) for each experimental condition.

Table 1. Mean RT (ms) and percentage of errors (between parentheses) for each experimental condition.

		No alerting Tone			Alerting Tone		
		Neutral (No-cue)	**Valid (Cued)**	**Invalid (Uncued)**	**Neutral (No-cue)**	**Valid (Cued)**	**Unvalid (Uncued)**
Non-experienced Drivers	**Congruent**	529	501	528	480	467	517
	Incongruent	593	563	608	576	546	621
Experienced Drivers	**Congruent**	614	559	595	544	538	570
	Incongruent	660	655	677	648	625	651
Total	**Congruent**	571	530	562	512	503	544
	Incongruent	627	609	643	612	585	636

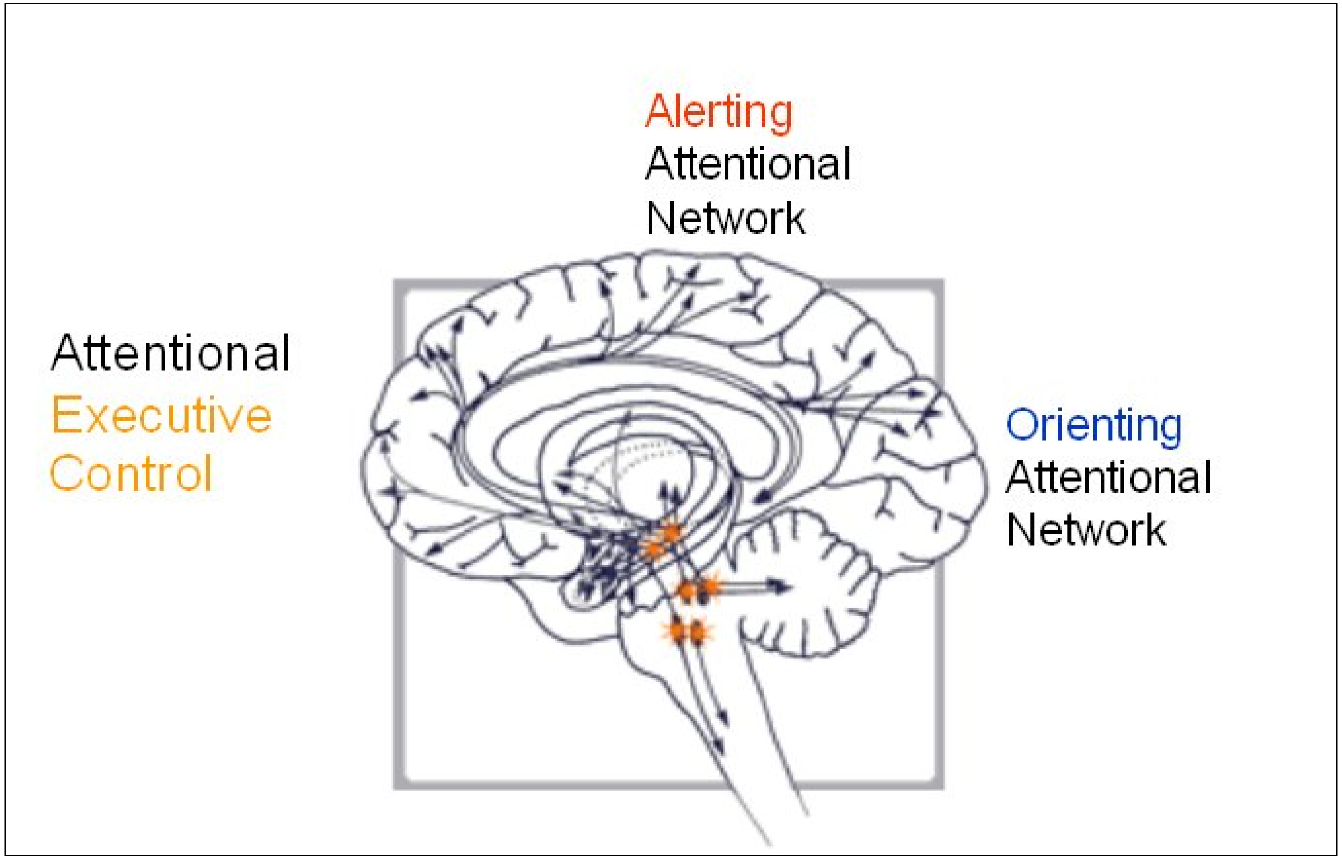
Figure Captions

Figure 1. The three attentional networks: alerting, orienting and executive attention. Posner (1978, 1980). These networks have now been defined in anatomical and functional terms. Alerting attentional network located in frontal & parietal regions (right hemisphere), attentional executive control located in the frontal cortex and orienting attentional network located in the superior parietal lobe.

Figure 2. **A** and **B** represent the procedure and stimuli used in this experiment, respectively.

Figure 3. Top/Bottom: Results for Non-experienced vs. Experienced Drivers, respectively: **A.** Graphic representation of the interaction between Congruency and Visual Cue. The *y-axis* represents the congruency effect in ms (incongruent trials minus congruent trials); **B.** Graphic representation of the interaction between Congruency and Auditory Signal. The *y-axis* represents the congruency effect in ms; **C.** Graphic representation of the interaction between Visual Cue and Auditory Signal. The *y-axis* represents the Orienting effect in ms (uncuded-invalid trials minus cued-valid trials).

Figure 1


Alerting
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Control
Orienting
Attentional
Network

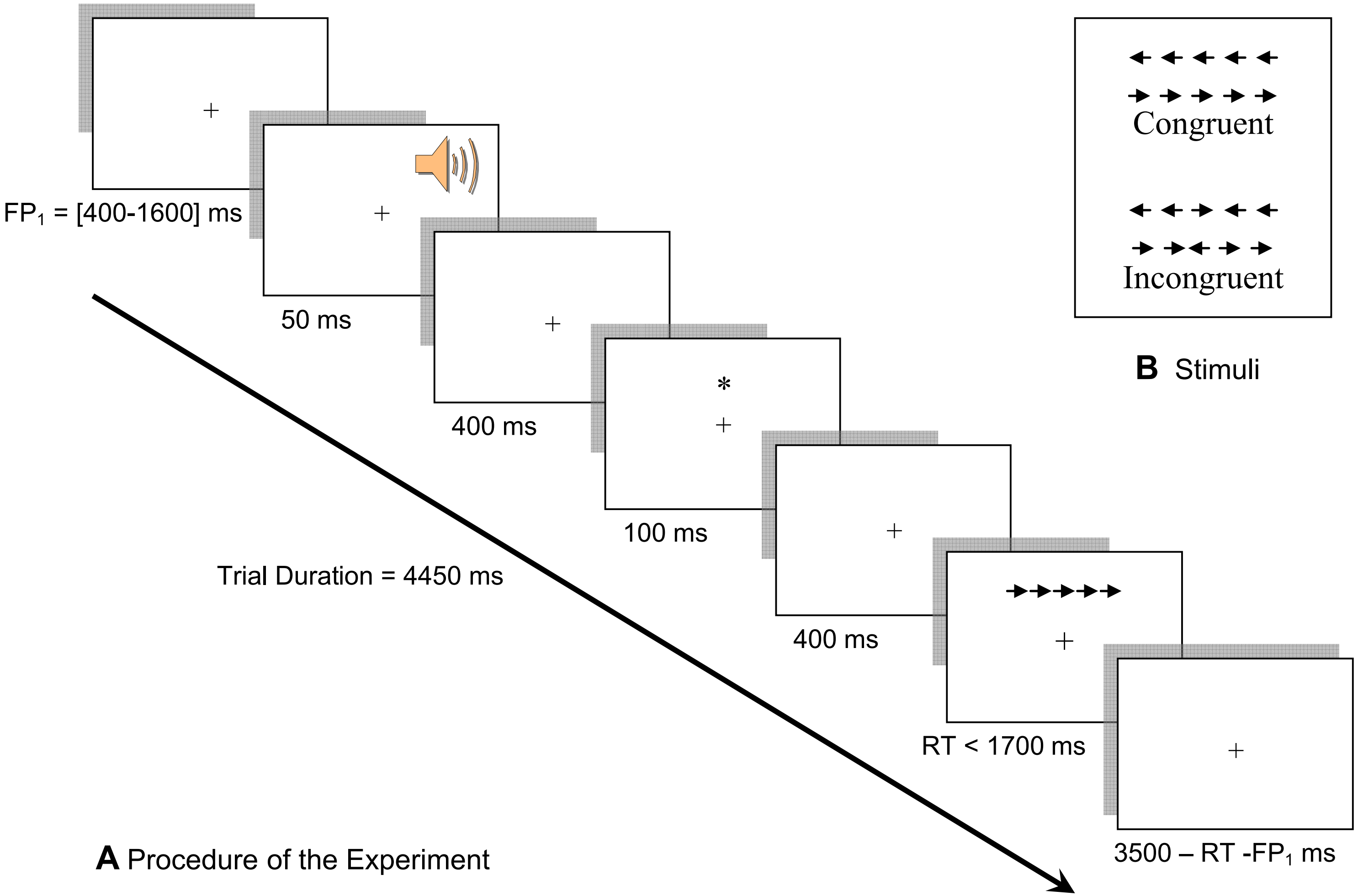


Figure 2. **A** and **B** represent the procedure and stimuli used in this experiment, respectively.

Figure 3-Top. Non-experienced Drivers

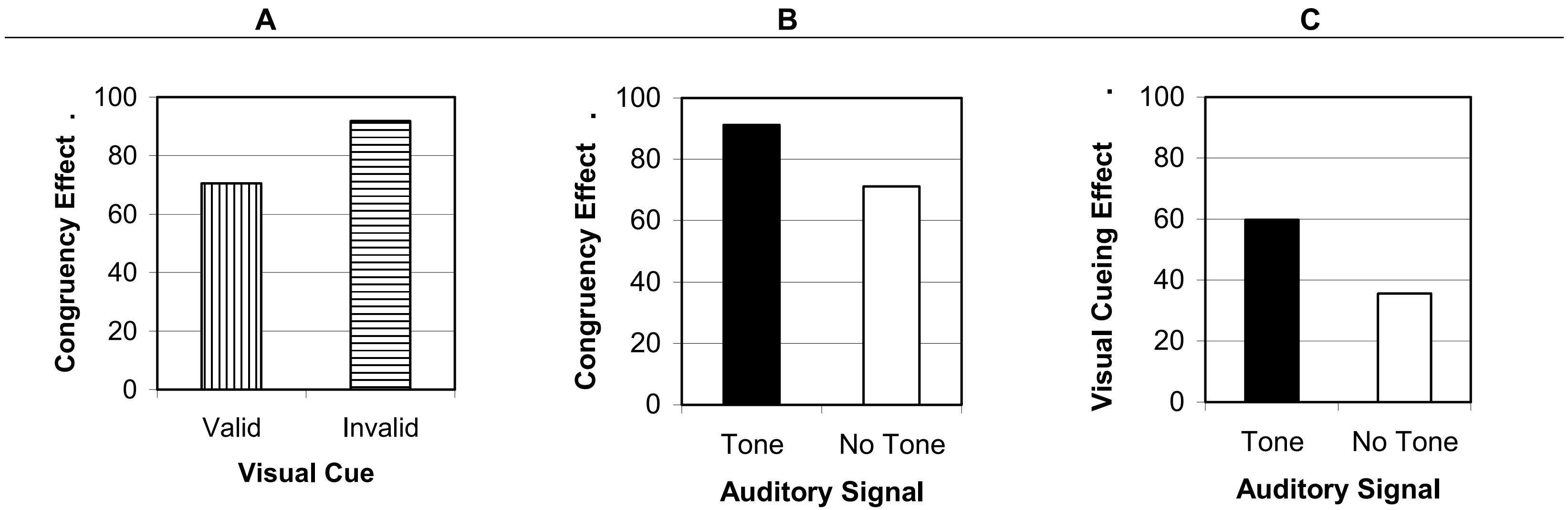
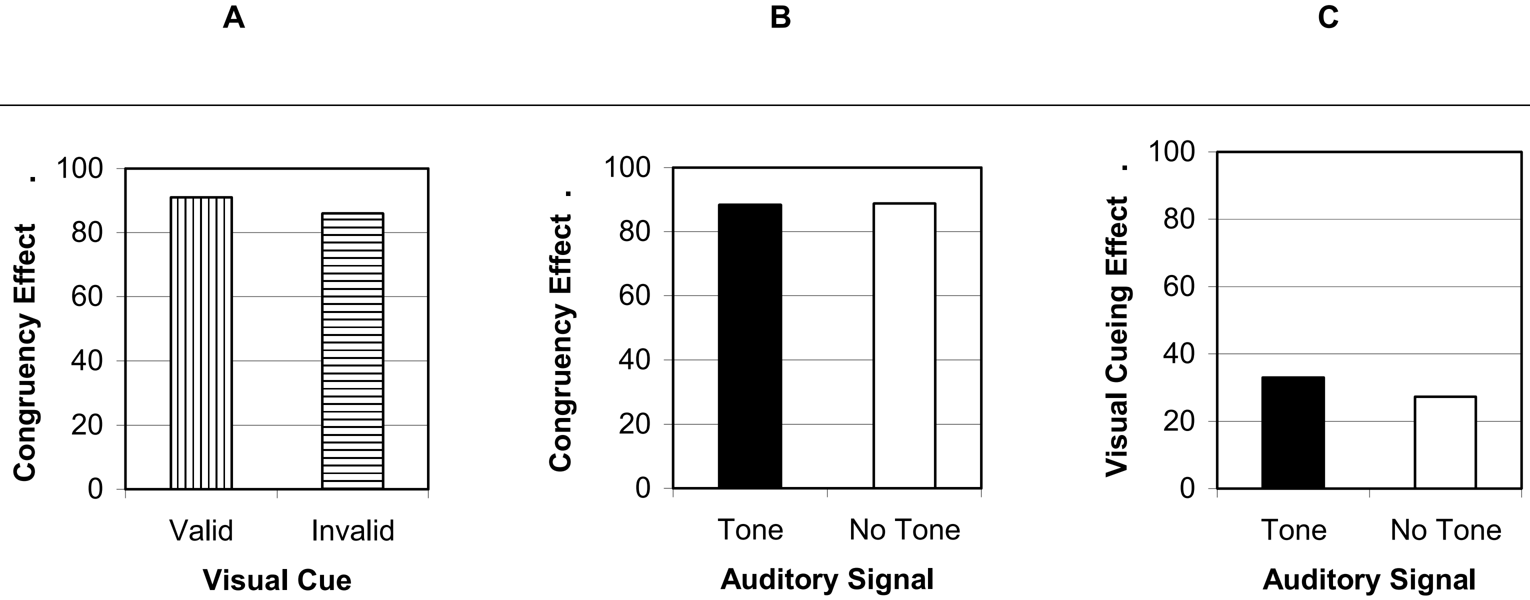


Figure 3-Bottom. Experienced Drivers



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Re: New article submission to Transportation Research Part F

Dear Sir or Madam,

Please find enclosed five copies of the article entitled **Driving Experience and the functioning of the Three Attentional Networks** to be considered as a contribution to Transportation Research Part F.

Please contact me (candida@ugr.es) if you require anything.

Sincerely,

Dr Candida Castro
Email: candida@ugr.es

Enclosures