# Telephone Conversations Affect the Executive but not the Alerting or Orienting Network

Daniel O.A. Gunnell, Melina A. Kunar, Rhiannon H. Richards and Derrick G. Watson

Corresponding Author: Melina Kunar

Department of Psychology, The University of Warwick, Coventry, CV4 7AL, UK

Tel: +44 2476 522133

Email:

M.A.Kunar@warwick.ac.uk

D.G.Watson@warwick.ac.uk

rhiannonrichards97@gmail.com

dgunnell777@gmail.com

Running Head: Phone Conversations and the Attentional Network Task

## Author Note

The study design, hypotheses and analytic plan were not pre-registered. All data, materials and programming code can be found on the Open Science Framework (https://osf.io/6kvnb/). This work was supported by an ESRC collaborative studentship awarded to Dan Gunnell, Derrick Watson and Melina Kunar

## Abstract

Previous work has shown that talking on a mobile phone leads to an impairment of visual attention. Gunnell et al. (2020) investigated the locus of these dual-task impairments and found that although phone conversations led to cognitive delays in response times, other mechanisms underlying particular selective attention tasks were unaffected. Here we investigated which attentional networks, if any, were impaired by having a phone conversation. We used the Attentional Network Task (ANT) to evaluate performance of the alerting, orienting and executive attentional networks, both in conditions where people were engaged in a conversation and where they were silent. Two experiments showed that there was a robust delay in response across all three networks. However, at the individual network level, holding a conversation did not influence the size of the alerting or orienting effects but it did reduce the size of the conflict effect within the executive network. The findings suggest that holding a conversation can reduce the overall speed of responding and, via its influence on the executive network, can reduce the amount of information that can be processed from the environment.

Key Words: Mobile Phone Conversation, Dual-task, ANT, Attention, Executive Control

## Public Significance Statement

This study suggests that having a phone conversation leads to a general overall slowing of response times. Furthermore, having a conversation affects how we perform specific tasks that require a higher degree of attentional control (those that use the ‘executive’). This has implications for performing complex tasks such as driving, thought to involve these higher-level functions.

# Introduction

Doing two tasks at once can lead to detriments in performance. In some situations, this may be of little consequence, in others it can be severe. For example, talking on a mobile phone, can lead to longer response times and more errors in a driving simulated task compared to when people are not having a conversation (Strayer & Johnston, 2001). Furthermore, talking on a mobile phone can result in a deficit in the ability to recall objects that have been directly fixated during the conversation (Strayer and Drews, 2007). Interestingly, the dual-task impairment of talking on a mobile phone is not a direct result of the manual conflict of physically holding a phone while driving as the interference is also observed when conversing on hands-free devices (e.g., Strayer & Johnston, 2001, Strayer, Drews, & Crouch, 2006; Strayer & Drews, 2007; Bergen et al., 2013; Sanbonmatsu et al., 2016). Instead, having a conversation leads to a deficit in cognitive resources needed to do other tasks. One important component of the dual-cost of talking on a mobile phone is the role it plays in disrupting our ability to pay attention to our surroundings (Kunar et al., 2008). This issue is increasingly important given the high proportion of accidents that occur as a result of drivers' inattention (Beanland et al., 2013).

Previous work has used lab-based experiments to determine deficits in visual attention while talking on a hands-free phone. Kunar et al. (2008) showed that participants' ability to track multiple targets in a Multiple Object Tracking (MOT) task was impaired (a task used to measure sustained attention, Pylyshyn & Storm, 1988, Horowitz et al., 2007, Wolfe, Place & Horowitz, 2007). Participants' reaction times (RTs) were significantly longer, and error rates increased when having a conversation compared to when participants performed the task in silence. Furthermore, Kunar et al. (2018) showed that having any kind of conversation led to an increase in response times in the MOT task, regardless of whether the conversation was considered easy or difficult. Both types of conversation led to a deficit in the ability to track multiple items. Lastly, people were impaired on a single feature search task which required minimal attentional resources. In this task participants were asked to search for a unique red item among green distractor items. Typically, people can find the target in this type of display very efficiently (Treisman & Gelade, 1980). Despite this, having a conversation led to a substantial increase in RTs, compared to when people completed the task in silence (Kunar et al., 2018).

It has been shown that having a phone conversation impairs attention, however, which attentional mechanisms are affected remain largely unknown. It has been proposed that having a conversation leads to a central attentional bottleneck, akin to that of the Perceptual Refractory Period (PRP, Welford et al., 1952; Pashler, 1994; Levy, Pashler & Boer, 2006; Kunar et al., 2008). This theory states that given the limit in attentional resources, if two stimuli compete for processing then one would be processed before the other. The second stimulus would be delayed in processing until such a time that the resources have become freed, and processing of the second stimulus can begin. Kunar et al. (2008) proposed that with respect to attention and conversations, the competition for resources would have to occur at a central, amodal level, given that the tasks primarily originate from different modalities (e.g., vision for attention and auditory and speech production for the conversation).

Bergen et al. (2013) also investigated whether the deficit of having a phone conversation on driving behaviour occurred due to Domain-General interference or Domain-specific interference. Domain-General theories suggest that there is one overall attentional resource pool that is needed for all modalities (akin to the attentional capacity theory proposed by

Kahneman, 1973). This suggests that any two tasks, regardless of their modality, would compete for the same attentional resource. In contrast, Domain-Specific theories suggest that there are multiple resource pools for different modalities (akin to the Multiple Resource Theory proposed by Wickens, 1984, 2002). This suggests that tasks would only compete for attentional resources, and thus interfere with each other, if they shared an overlap in modality or processing codes. In their research, Bergen et al, (2013) found evidence for both Domain-General interference in a participants' braking RTs and Domain-Specific interference in a distance following task (in which participants were asked to maintain a specific distance from a lead vehicle).

Gunnell et al. (2020) investigated whether conversational competition for attentional resources would lead to interference of specific attentional *mechanisms*, or whether it would just lead to a delay in our ability to respond. They investigated this using the mechanisms of Contextual Cueing (CC) and Visual Marking (VM). Contextual Cueing demonstrates the visual system's ability to use repeated patterns to facilitate target detection (either by providing a benefit to guidance or response selection in search, Chun & Jiang, 1998; Kunar et al., 2007, 2014a, 2014b, see Sisk et al., 2019 for a review). Visual Marking refers to the ability to de-prioritise irrelevant stimuli, so they do not compete for attention (Watson & Humphreys, 1997, Watson & Kunar, 2010, Watson & Kunar, 2012). Both of these processes are thought to use attentional networks associated with the Parietal Cortex (e.g., Giesbrecht et al., 2012; Humphreys et al., 2004). Gunnell et al. (2020) investigated whether having a conversation led to these mechanisms being disrupted. That is, whether under conversation conditions a CC or VM effect would fail to occur, or whether the effects would still be observed but there would be a delay in response (supporting a Cognitive Delay account). Across six experiments it was found that CC and VM effects remained under conversation conditions, however there was a consistent and robust cognitive delay. The results showed these *attentional mechanisms* were immune to dual-task conversational interference, yet people were significantly slower in making a response.

Both Visual Marking and Contextual Cueing require the use of the parietal areas and involve inhibitory and memory processes. However, many tasks in everyday life use different types of attentional networks, controlled by different areas of the brain (e.g., executive functions are thought to be regulated by the frontal lobes, Alvarez & Emory, 2006). Consider the task of driving, in which there are multiple cognitive tasks that all require different aspects of attention (see Weaver et al., 2009). Some of the tasks may require vigilance or alerting to detect unexpected events (e.g., a car suddenly braking or changing lane). Other tasks may require drivers to direct or orientate their attention to different spatial locations (e.g., car indicators, directional traffic signs). Further still, other aspects of driving may require higher levels of attentional control, such as tasks involved in conflict resolution to inhibit distracting information. In accordance with this, Posner and Petersen (1990; Petersen & Posner, 2012) have proposed that there are three general networks involved in controlling and maintaining attention: alerting, orienting and executive control. To our knowledge the effect of mobile phone conversations on these distinct types of attentional processes has not yet been investigated. Research into this area is important to determine the potentially different effects that conversations might have in tasks that engage these different types of attentional networks.

Accordingly, in the current study, we examined the influence of hands-free phone conversations on these three different attentional networks. Posner and Petersen (1990, Peterson & Posner, 2012) proposed that the alerting, orienting and executive networks are all distinct and represent different attentional processes. The *alerting* network signals that attention is required and maintains a general level of attentional arousal needed to perform a task efficiently. The *orienting* network prioritizes competing signals, directing attention, for example, to the appropriate sensory modality or spatial location. The *executive* network mediates target selection, error detection, and conflict resolution. This network allows us to filter conflicting information and establish if inputs are important for task completion or whether they should be ignored (for reviews see Petersen and Posner, 2012, Posner, 2008, Fan et al., 2005).

Fan et al., (2002) developed the Attention Network Task (ANT) to study these attentional networks. On each trial, participants indicate the direction of a leftward-pointing or rightward-pointing target arrow, presented above or below fixation and flanked by two adjacent distractors. Visual cues might precede each trial. The operation of the *alerting network* is measured by comparing performance on no-cue trials with performance when two cues indicate both potential target locations. The *orienting network* is examined by comparing performance when a single cue indicates the target location with performance when a non-informative cue is presented at fixation. The *executive control network* is examined by manipulating the identity of the flankers (response congruent, incongruent or neutral) which present irrelevant and distracting information (Eriksen & Eriksen, 1974; Eriksen, 1995). Importantly, within the executive network, a comparison of responses on congruent and incongruent trials shows the 'conflict effect', in which larger conflict values indicate greater interference from the task-irrelevant flanking items (Fan et al., 2002, Berman, Jonides & Kaplan, 2005).

Given the consistency of the Cognitive Delay found across previous experiments, one could hypothesise that being engaged in a conversation would impair the function of each network equally. That is, the performance of each network would remain the same, however, all networks would show a response delay due to conversational demands. Alternatively, given the independence of the three networks (Petersen & Posner, 2012) it is possible that, along with a cognitive delay, conversation could also have a selective impact on the operations of each network. For example, abruptly appearing stimuli can capture our attention involuntarily (Yantis & Jonides, 1984; Remington, Johnston, & Yantis, 1992; Theeuwes, 1994) or whilst attention is engaged elsewhere (Conway, Cowan, & Bunting, 2001). Therefore, we might expect the alerting network to be immune to conversation. The orienting network is thought to be involved in spatial location information in search and is associated with the superior parietal lobe (Corbetta et al., 2000). Given that this area is also associated with both CC (Giesbrecht et al., 2012) and VM (Humphreys et al., 2004) – mechanisms that were not affected by conversation - it may be that the orienting network would also be immune to the effects of conversation.

However, the effect of conversation on the executive control network is more challenging to predict. Gunnell et al. (2020) suggested that the cognitive delay could occur due to participants having to task-switch between allocating attention to the conversation and the visual task. Task-switching is also often thought to be associated with executive control (Kiesel et al., 2010, Kray et al., 2011). Therefore, if the executive network is already being used for task-switching then this network could be affected under conversation conditions. As noted above, within the ANT, the executive network is involved in conflict resolution under conditions in which people are processing competing distractors alongside the target (see also Fan et al., 2002, Berman, Jonides & Kaplan, 2005). Accordingly, the size of this conflict effect tells us the extent to which holding a conversation modulates the ability to ignore competing information. In some situations, the ability to ignore competing information will have no effect, and may even enhance, a task. Take the example of driving, where there is often a large amount of information to be processed (e.g., billboards, parked cars, shops, road signs, pedestrians etc). For the most part, filtering out these other stimuli is helpful, as they may be distracting while focussing on the road. However, in some situations these stimuli could become important (e.g., a pedestrian wanting to cross the road). Given the dynamic and varied task of driving and that it is not always possible to predict, a priori, when a stimulus will become relevant (especially in the case of pedestrians and other vehicles), the ability to process and be aware of surrounding information is critical.

In overview, we present two experiments that use the ANT to investigate how conversation affects the alerting, orienting and executive networks. In Experiment 1, participants completed the ANT task either on its own or while conversing with the experimenter. The results showed that holding a conversation increased RTs overall. Furthermore, conversation had no discernible effect on the size of the alerting or orienting effects but reduced the size of the conflict effect in the executive network. This modulation in conflict effect suggests that the amount of resources available to process items on the display was reduced when having a conversation. Accordingly, in Experiment 2 we added an additional task which is known to require executive function (a Backward Digit Span task, Grégoire & Van der Linden, 1997). This 'executive' digit span task provided a baseline to show how response to the ANT was disrupted when participants were engaged in a task that is known to be predominantly executive in nature.

In accordance with Fan et al. (2002) the ANT task included trials that used four cue conditions (no cue, centre cue, double cue, spatial cue) and three types of flankers (congruent, incongruent and neutral), which allowed performance to be measured in the different networks[1]. Reaction Time (RT) differences between the no cue and double cue conditions were used to measure the alerting effect in the alerting network. RT differences between the centre cue and spatial cue conditions were used to measure the orienting effect in the orienting network. RT differences between the incongruent and congruent conditions were used to measure the conflict effect in the executive condition. If conversation impairs RTs across all three networks, we can conclude that this cognitive delay is consistent with a Domain-General theory of interference. If, however, we also observe differential effects on each network (as shown by significant interactions between conversation and cue or flanker types), this would suggest that the dual-task cost of holding a conversation leads to domain specific impairments, consistent with a Domain-Specific theory.

## Experiment 1

## Method

### *Transparency and Openness*

All data, materials and programming code can be found on the Open Science Framework (https://osf.io/6kvnb/). Experimental programs were written in BlitzMax (Version 1.48 Sibly, 2004) for Experiment 1 and PsychoPy, for online data collection using Pavlovia (Peirce et al., 2019) for Experiment 2. All data were compiled in Microsoft® Excel® for Microsoft 365 MSO (Version 2112 Build 16.0.14729.20254) and imported into JASP (Version 0.16; JASP Team,

[1] The target appeared either above or below fixation and could face either the left or the right.

2021) for statistical analysis. The study design, hypotheses and analytic plan were not pre-registered. All manipulations, data exclusions and measures are reported.

*Participants*

Forty participants (34 female, 6 male, Mean age = 20.7) were recruited from the undergraduate Psychology and the Decision Research participant pools at the University of Warwick. Participants received course credit or £5 for taking part and had normal or corrected to normal vision. Ethical approval was granted by the Department of Psychology Ethics Committee at the University of Warwick. The number of participants was guided by Fan et al. (2002, who tested 40 people). A power analysis was calculated via G*Power (Faul et al., 2007), which used a medium effect size of 0.5 (paired t-test, alpha = 0.05) consistent with Cohen's guidelines (1988). This calculation indicated that the minimum number of participants needed to achieve a power of 0.8 for each experiment was 34. Therefore, we would expect that testing 40 participants would provide sufficient power to detect significant effects, if present.

*Stimuli and Apparatus*

The ANT task was presented using a custom written computer program, following the specifications given by Fan et al. (2002). The program ran on an i3 RM PC Computer attached to a Hanns-G LCD monitor running at a resolution of 800×600. Participants responded using a standard QWERTY keyboard. The conversation took place over a Samsung Galaxy S4 smart phone via SKYPE. The experimenter received the call on a Toshiba Satellite Pro Laptop computer.

*Design*

A 2 (Conversation condition: Conversation, No Conversation) × 4 (Cue type: no cue, central cue, double cue, spatial cue) × 2 (Target location: above or below fixation) × 2 (Target direction: Left, Right) × 3 (Flanker: Incongruent, Congruent, Neutral) within-subjects design was used. The dependant variables were RTs and error rate. Participants completed one block of 24 full feedback practice trials followed by six blocks of 96 experimental trials. In half of the experimental blocks participants held a naturalistic conversation with the experimenter. Conversation blocks alternated with no-conversation blocks in a counterbalanced order. The trial structure replicated that of Fan et al., (2002) and used a visual alerting cue to avoid auditory interference from the conversation.

Each trial consisted of a central fixation cross presented for 400-1600ms, followed by one of four possible cues. In the central cue condition an asterisk replaced the fixation cross. In the double cue condition an asterisk appeared above and below the fixation cross in the two possible target locations. In the spatial cue condition a single asterisk appeared at one of the target locations and always indicated the proceeding target location. The cue remained visible for 100ms in all cue conditions. In the no-cue condition the fixation remained until the target appeared (see Figure 1).

-----------------------------------------

Figure 1 about here

-----------------------------------------

Following the cue, the central fixation cross remained alone for a further 400ms after which the target appeared either above or below the central fixation cross accompanied by two horizontally adjacent flankers. The flankers were either congruent (arrows pointing in the same direction as the target), incongruent (arrows pointing in the opposite direction) or neutral (lines without arrowheads). The target remained visible until the participant indicated the direction of the target arrow or 1700ms had elapsed. At this point the display was replaced by a fixation cross until the trial duration reached 4000ms (see Figure 2).

-----------------------------------------

Figure 2 about here

-----------------------------------------

*Procedure.*

Participants sat approximately 57cm from the computer screen, read through the task instructions and gave informed consent. They then completed 24 practice trials, randomly selected without replacement from the 48 possible trial variations. Participants were invited to ask any questions and were reminded that for half of the experimental blocks they would be holding a naturalistic conversation with the experimenter, which would be recorded. The conversation took place over a hands-free mobile phone using SKYPE VOIP software. The experimenter received the call on a laptop computer in an adjacent experimental cubicle. During the conversation, the experimenter’s task was to ensure equal participation in the conversation from both parties. The conversation was to be as naturalistic as possible and so participants were given scope to take the conversation in any direction, within reason. Care was taken to avoid emotionally salient topics. In general, the conversations followed a very similar pattern of discussing life at university, the participants’ thoughts on their course, their home life and/or their holidays/travelling.

Participants then completed six blocks of 96 trials. Each block contained every possible combination of conditions, twice. Participants were instructed to look at the central fixation point until the target appeared on the screen and respond to the orientation of the target arrow by pressing the < key if the target was pointing to the left and the > key if it was pointing to the right. If participants did not respond within 1700ms the trial automatically moved on and a "no response" was recorded.

## Results

Trials in which participants did not respond in time (1700ms) or responded too quickly (< 200ms) were removed prior to the analysis (1.6% of trials). In addition to frequentist statistics, we also report Bayes Factors analyses for all t-tests (calculated with a Cauchy prior width of 0.707 using JASP version 0.9.2)[2]. We adopted the recommendations of Jeffreys (1961), in which a $BF_{10}$ of 1 to 3 provides *anecdotal* evidence for the alternative hypothesis, a $BF_{10}$ of 3 to 10 provides *substantial* evidence for the alternative, a $BF_{10}$ of 10 to 30 provides *strong* evidence for the alternative, a $BF_{10}$ of 30 to 100 provides *very strong* evidence for the alternative and a $BF_{10}$ of greater than 100 provides *decisive* evidence for the alternative. The inverse of these numbers ($BF_{01}$) provide evidence in support of the null hypothesis (Jarosz & Wiley, 2014). Mean correct RTs for each condition are shown in Table 1 and Figure 3 shows the mean alerting, orienting and conflict effects across conversation conditions. Error rates are shown in Table 2.

-----------------------------------------

Tables 1 and 2 and Figure 3 about here

-----------------------------------------

### *RTs*

[2] Please note we only include Bayesian statistics for t-tests as these statistics are generally accepted. At present research is ongoing on how best to interpret Bayes factors for repeated measures ANOVAs (Wagenmakers et al., 2018).

*Alerting Network*

Mean correct RTs were entered into a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Cue (Double vs No Cue) as factors. RTs were longer in the Conversation compared to the No Conversation condition, $F(1, 39) = 40.85$, $p < .001$, $\eta_p^2 = 0.51$, and longer in the No Cue compared to the Double Cue condition, $F(1, 39) = 148.59$, $p < .001$, $\eta_p^2 = 0.79$. The Conversation x Cue interaction was not significant, $F(1, 39) = 0.06$, $p = .81$, $\eta_p^2 = 0.002$. In accordance with Fan et al. (2002) we calculated the alerting effect of the alerting network, by subtracting mean correct RTs in the Double cue condition from those of the No cue condition. A paired-samples t-test showed that the difference in alerting effects between the Conversation and No conversation condition was not significant, $t(39)= 0.25$, $p =.81$, $d = .04$, with substantial evidence in support of the null, $BF_{10} = 0.18$[3].

*Orienting Network*

Mean correct RTs were entered into a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Cue (Central vs Spatial) as factors. RTs were longer in the Conversation compared to the No Conversation condition, $F(1, 39) = 44.16$, $p < .001$, $\eta_p^2 = 0.53$, and longer in the Central compared to the Spatial Cue condition, $F(1, 39) = 77.82$, $p < .001$, $\eta_p^2 = 0.67$. The Conversation x Cue interaction was not significant, $F(1, 39) = 0.50$, $p = .48$, $\eta_p^2 = 0.01$. To calculate the orienting effect of the orienting network, mean RTs from the Spatial cue condition were subtracted from the Central cue condition. A paired-samples t-test showed that the difference in orienting effects between the Conversation and No

[3] In Experiment 1, the alerting, orienting and conflict effects duplicate the results provided by the interaction term of the ANOVAs. However, we include them in the paper to show the frequentist counterpart of the Bayesian statistics.

conversation condition was not significant, $t(39)= 0.71$, $p = .48$, $d = 0.11$, with substantial evidence in support of the null, $BF_{10} = 0.22$.

*Executive Control*

Mean correct RTs were entered into a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Congruence (Congruent vs Incongruent) as factors. RTs were longer in the Conversation compared to the No Conversation condition, $F(1, 39) = 38.53$, $p < .001$, $\eta_p^2 = 0.50$, and longer in the Incongruent compared to the Congruent condition, $F(1, 39) = 214.54$, $p < .001$, $\eta_p^2 = 0.85$. The Conversation x Congruence interaction was also significant, $F(1, 39) = 17.03$, $p < .001$, $\eta_p^2 = 0.30$. To calculate the conflict effect of the executive network RTs of the Congruent conditions were subtracted from those of the Incongruent conditions. A paired-samples t-test showed that the conflict effect of the executive network was reduced in the Conversation compared to the No Conversation condition, $t(39)= 4.13$, $p < .001$, $d = .65$, with decisive evidence in support of the alternative, $BF_{10} = 137.4$.

*Errors*

Alongside RTs we also analysed error rates to examine whether the data were affected by speed-accuracy trade-offs.

*Alerting Network*

Mean errors were entered into a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Cue (Double vs No Cue) as factors. More errors were made in the No Conversation compared to the Conversation condition, $F(1, 39) = 6.78$, $p = .013$, $\eta_p^2 = 0.15$.

There was no main effect of Cue, $F(1, 39) = 1.23$, $p = .27$, $\eta_p^2 = 0.03$. The Conversation x Cue interaction was also non-significant, $F(1, 39) = 1.12$, $p = .30$, $\eta_p^2 = 0.03$[4].

*Orienting Network*

Mean errors were entered into a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Cue (Central vs Spatial) as factors. There was no main effect of Condition, $F(1, 39) = 3.81$, $p = .06$, $\eta_p^2 = 0.09$. There was a main effect of Cue, $F(1, 39) = 6.53$, $p = .015$, $\eta_p^2 = 0.143$, in which there were more errors in the Central compared to the Spatial Cue condition. The Conversation x Cue interaction was non-significant, $F(1, 39) = 0.21$, $p = .65$, $\eta_p^2 = 0.005$.

*Executive Control*

Mean errors were entered into a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Congruence (Congruent vs Incongruent) as factors. More errors were made in the No Conversation compared to the Conversation condition, $F(1, 39) = 8.00$, $p = .007$, $\eta_p^2 = 0.17$. There was also a main effect of Congruence, $F(1, 39) = 48.66$, $p < .001$, $\eta_p^2 = 0.555$, in which there were more errors in the Incongruent conditions compared to Congruent trials. The Conversation x Congruence interaction was non-significant, $F(1, 39) = 3.24$, $p = .08$, $\eta_p^2 = 0.077$.

## Discussion

[4] Given that the operation of the ANT network is determined by RT response and not error rates (Fan et al., 2002), error rates, unlike RTs, were not analysed further in terms of network performance.

Experiment 1 examined how having a phone conversation impacted performance within the alerting, orienting and executive networks. Importantly, across all three networks the results showed a delay in response. Participants were slower to respond in the Conversation condition compared to the No Conversation condition. This is consistent with the Cognitive Delay account proposed by Gunnell et al. (2020).

However, holding a conversation had differential effects across the three individual networks. The results showed that holding a conversation did not significantly change the size of the alerting and orienting effects. However, participants showed a reduced conflict effect in the executive network when having a conversation compared to when they were not. To calculate the conflict effect, congruent RTs were subtracted from incongruent RTs. This measure indicates how much the incongruent distractors interfered with responses to the target. Although RTs were higher in the Conversation condition overall, the conflict effect and thus the amount of distraction from the distractors was greater in the No Conversation condition than in the Conversation condition. One reason for this might be to do with perceptual load. Perceptual Load Theory suggests that under conditions of difficulty or high perceptual load, fewer attentional resources are available to process competing information (Lavie & Tsal, 1994 Lavie, 1995, Lavie, 2005). In relation to our experiment, the process of having an active conversation would lead to fewer resources being available to process the incongruent distractors. We investigate this further in Experiment 2, in which we include an additional condition that is known to require executive resources to show how the conflict effect changes when people are performing a predominantly executive function.

The results also showed that participants made more errors in the No Conversation condition than the Conversation condition for both the alerting and executive conditions. Please note that this only applied to the main effects and not the interactions (which were important for determining each networks' performance). Nevertheless, this increase in errors could have implications for the cognitive delay effect if participants were sacrificing accuracy for speed. Given that error rates were low throughout the experiment (1.3% overall) we do not think that speed-accuracy trade-offs were responsible for the longer RTs observed. However, to examine this further we replicated the conditions in Experiment 2. If the delays in alerting and executive response times were due to people making slower but more accurate responses in the Conversation condition, we would expect to replicate the speed-accuracy trade-offs here.

As mentioned above, the data from Experiment 1 showed that conversation affected the executive network. This suggests that impact of conversation is specific to one attentional network, in line with a domain-specific account of dual-task performance. To investigate this further, in Experiment 2, we included a condition in which participants completed a well-known 'executive' task, while completing the ANT. Here participants were asked to complete a Backwards Digit Span task, in which they heard a series of four-digit numbers and were asked to repeat each one back to the experimenter in the reverse order (e.g., after hearing '2841' participants would repeat back '1482'). As this Backwards Digit Span task required the use of the executive function (Grégoire & Van der Linden, 1997) we predicted there would be a strong domain-specific affect with the executive network (but not in the alerting or orienting networks). The conflict effect found in the Backwards Digit Span task was also used to compare to that found in the executive network when having a conversation.

# Experiment 2

## Method

### *Participants*

Forty participants (22 females, 15 males, and 1 non-binary, 2 participants preferred not to disclose their gender, Mean age = 24.9 years, 6 participants preferred not to disclose their age) were recruited from the undergraduate Psychology and the Decision Research participant pools at the University of Warwick. Participants received a £5 Amazon Voucher for taking part and had normal or corrected to normal vision. Ethical approval was granted by Humanities and Social Sciences Research Ethics Committee (HSSREC 118/20-21) at the University of Warwick.

### *Stimuli and Apparatus*

The stimuli and apparatus were similar to Experiment 1, except that the experiment was programmed using PsychoPy and run online via Pavlovia (Peirce et al., 2019). The experiment was coordinated, and participant-experimenter interaction was conducted via Microsoft® Teams® (Version 1.4.00.32771).

### *Design*

The experiment was similar to that of Experiment 1 except that, squares were used instead of asterisks as cues, and arrow heads were used instead of arrows. All stimuli were black and were presented on a grey background. For each condition participants completed three blocks of 96 experimental trials.

*Procedure*

There were three experimental conditions: Conversation, No Conversation and Backwards Digit Span. The Conversation and No Conversation conditions were the same as those in Experiment 1, except that all trials within each condition were run as a separate block. The Backwards Digit Span condition was similar to the Conversation condition, except instead of having a conversation, participants engaged in a task where they had to verbally repeat a sequence of digits back to the experimenter in reverse order. Digits were presented to the participant in the auditory domain at a rate of approximately 1 per second. Participants waited until they had heard the whole sequence before providing their response. They were not given feedback and if a mistake was made or if they were unable to recall the digits the experimenter moved onto the next digit sequence. Digit sequences were 4 digits in length, given that the average digit span for correct backwards recollection is between 4 and 5 digits for participants aged between 18 – 70 years[5] (Grégoire & Van der Linden, 1997).

## Results

Data from two people were incomplete, and so were not analysed. Trials in which participants did not respond in time (1700ms) or responded too quickly (< 200ms) were removed as outliers. Three participants showed overall outliers of above 20% (20.7%, 45.2% and 52.0%, respectively) and so were removed from further analysis. From the remaining participants 2.4% of the total data were removed as outliers. Figure 4 shows the mean alerting, orienting and

[5] We chose to use the lower limit of the digit span sequence on the assumption that the task would be difficult, while completing alongside the ANT.

conflict effects across conditions. Mean correct RTs and Error rates for all conditions can be seen in Table 3 and 4, respectively.

----------------------------------------

Tables 3 and 4 and Figure 4 about here

----------------------------------------

*RTs*

*Alerting Network*

Mean correct RTs were entered into a within-participants ANOVA with Condition (Conversation, Digit Span, No Conversation) and Cue (Double vs No Cue) as factors. There was a main effect of Condition, $F(2, 68) = 37.99$, $p < .001$, $\eta_p^2 = 0.53$, in which RTs were longest in the Digit Span condition followed by the Conversation and then the No Conversation Condition. There was also a main effect of Cue, $F(1, 34) = 60.28$, $p < .001$, $\eta_p^2 = 0.64$, in which RTs were longer in the No Cue compared to the Double Cue condition. The Conversation x Cue interaction was non-significant, $F(2, 68) = 1.25$, $p = 0.29$, $\eta_p^2 = 0.04$. Paired-samples t-tests were used to show the difference in alerting effects between the different conditions. There was no difference in alerting effects between the Conversation and No conversation conditions, $t(34) = 1.87$, $p = .07$, $d = 0.32$, with anecdotal evidence in support of the null, $BF_{10} = 0.86$. Neither were there significant differences between the Digit Span and the No conversation condition, $t(34) = 1.05$, $p = .30$, $d = 0.18$, with substantial evidence in support of the null, $BF_{10} = 0.30$, or the Conversation and the Digit Span condition, $t(34) = 0.36$, $p = .73$, $d = 0.06$, with substantial evidence in support of the null, $BF_{10} = 0.19$.

*Orienting Network*

Mean correct RTs were entered into a within-participants ANOVA with Condition (Conversation, Digit Span, No Conversation) and Cue (Central vs Spatial) as factors. There was a main effect of Condition, $F(2, 68) = 47.70$, $p < .001$, $\eta_p^2 = 0.58$, in which RTs were longest in the Digit Span condition followed by the Conversation and then the No Conversation Condition. There was also a main effect of Cue, $F(1, 34) = 16.20$, $p < .001$, $\eta_p^2 = 0.32$, in which RTs were longer in the Central compared to the Spatial Cue condition. The Conversation x Cue interaction was non-significant, $F(2, 68) = 1.92$, $p = .16$, $\eta_p^2 = 0.05$. Planned t-tests showed there was no difference in orienting effects between the Conversation and No conversation conditions, $t(34) = 1.48$, $p = .15$, $d = 0.25$, with substantial evidence in support of the null, $BF_{10} = 0.49$. Neither were there significant differences between the Digit Span and the No conversation condition, $t(34) = 0.85$, $p = .40$, $d = 0.14$, with substantial evidence in support of the null, $BF_{10} = 0.25$, or the Conversation and the Digit Span condition, $t(34) = 1.62$, $p = .12$, $d = 0.27$, with anecdotal evidence in support of the null, $BF_{10} = 0.59$.

*Executive Control*

Mean correct RTs were entered into a within-participants ANOVA with Condition (Conversation, Digit Span, No Conversation) and Congruence (Congruent vs Incongruent) as factors. There was a main effect of Condition, $F(2, 68) = 41.30$, $p < .001$, $\eta_p^2 = 0.55$, in which RTs were longest in the Digit Span condition followed by the Conversation and then the No Conversation Condition. There was also a main effect of Congruence, $F(1, 34) = 193.98$, $p < .001$, $\eta_p^2 = 0.85$, in which RTs were longer in the Incongruent compared to the Congruent condition. The Conversation x Congruence interaction was also significant, $F(2, 68) = 13.67$, $p < .001$, $\eta_p^2 = 0.29$. Planned t-tests showed a decrease in conflict effects in the Conversation condition compared to the No conversation condition, $t(34) = 3.17$, $p = .003$, $d = 0.54$, with strong evidence in support of the alternative, $BF_{10} = 11.27$. There was a decrease in conflict effects in the digit span task in comparison to the No conversation condition, $t(34) = 4.70$, $p < .001$, $d = 0.79$, with decisive evidence in support of the alternative, $BF_{10} = 551.21$, and also a decrease in conflict effects in the digit span task in comparison to the conversation task, $t(34) = 2.60$, $p = .014$, $d = 0.44$, with substantial evidence in support of the alternative, $BF_{10} = 3.25$.

*Errors*

*Alerting Network*

Mean errors were entered into a within-participants ANOVA with Condition (Conversation, Digit Span, No Conversation) and Cue (Double vs No Cue) as factors. There was a main effect of Condition, $F(2, 68) = 7.62$, $p = .001$, $\eta_p^2 = 0.18$, in which there were more errors in the Digit Span condition followed by the No Conversation and then the Conversation Condition. There was no main effect of Cue, $F(1, 34) = 0.04$, $p = .84$, $\eta_p^2 = 0.001$. The Conversation x Cue interaction was significant, $F(2, 68) = 3.93$, $p = .02$, $\eta_p^2 = 0.10$.

*Orienting Network*

Mean errors were entered into a within-participants ANOVA with Condition (Conversation, Digit Span, No Conversation) and Cue (Central vs Spatial) as factors. There was a main effect of Condition, $F(2, 68) = 6.78$, $p < .001$, $\eta_p^2 = 0.17$, in which there were more errors in the Digit Span condition followed by the No Conversation and then the Conversation Condition. There was no main effect of Cue, $F(1, 34) = 0.38$, $p = .54$, $\eta_p^2 = 0.01$. The Conversation x Cue interaction was significant, $F(2, 68) = 6.53$, $p = .003$, $\eta_p^2 = 0.16$.

*Executive Control*

Mean errors were entered into a within-participants ANOVA with Condition (Conversation, Digit Span, No Conversation) and Congruence (Congruent vs Incongruent) as factors. There was a main effect of Condition, $F(2, 68) = 6.16$, $p = .003$, $\eta_p^2 = 0.15$, in which there were more errors in the Digit Span condition followed by the No Conversation and then the Conversation Condition. There was also a main effect of Congruence, $F(1, 34) = 47.90$, $p < .001$, $\eta_p^2 = 0.56$, in which there were more errors in the Incongruent compared to the Congruent condition. The Conversation x Congruence interaction was non-significant, $F(2, 68) = 1.47$, $p = .24$, $\eta_p^2 = 0.04$.

*Replication of Experiment 1: Speed-Accuracy Trade-Off*

Experiment 1 showed a possible speed-accuracy trade-off in overall RTs between the Conversation and No Conversation conditions in the alerting and executive networks. To investigate whether a similar effect occurred in Experiment 2, we directly compared RTs and error rates for the Conversation and No Conversation conditions across all three networks[6].

*RTs*

For the alerting network, a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Cue (Double vs No Cue) as factors showed that there was a main effect of Conversation, $F(1, 34) = 29.40$, $p < .001$, $\eta_p^2 = 0.46$, in which there were longer RTs in the Conversation condition than in the No Conversation condition. There was a main effect of Cue, $F(1, 34) = 70.78$, $p < .001$, $\eta_p^2 = 0.68$. The Conversation x Cue interaction was non-significant, $F(1, 34) = 3.48$, $p = .07$, $\eta_p^2 = 0.09$[7]. For the orienting network, a within-participants ANOVA

[6] We chose to analyse the RTs and errors for the Conversation and No Conversation condition together (without the digit span task) to focus purely on the question of a speed-accuracy trade-off between these two conditions. These analyses allowed direct replication and comparison to that of Experiment 1. If speed-accuracy trade-offs were responsible for the results we should see a clear replication of the results, here. However, the results showed no evidence of any speed-accuracy trade-offs.

[7] For the paired t-tests based on the interaction see the RT section above.

with Conversation (Conversation vs No Conversation) and Cue (Central vs Spatial) as factors showed that there was a main effect of Conversation, $F(1, 34) = 37.32$, $p < .001$, $\eta_p^2 = 0.52$, in which there were longer RTs in the Conversation condition than in the No Conversation condition. There was a main effect of Cue, $F(1, 34) = 7.99$, $p = .008$, $\eta_p^2 = 0.19$, in which RTs were longer with a central cue than with a spatial cue. The Conversation x Cue interaction was non-significant, $F(1, 34) = 2.19$, $p = .15$, $\eta_p^2 = 0.06$. For the executive network, a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Congruence (Congruent vs Incongruent) as factors showed that there was a main effect of Conversation, $F(1, 34) = 32.19$, $p < .001$, $\eta_p^2 = 0.49$, in which there were longer RTs in the Conversation condition than in the No Conversation condition. There was a main effect of Congruence, $F(1, 34) = 187.15$, $p = < .001$, $\eta_p^2 = 0.85$, in which RTs were longer in the Incongruent than in the Congruent condition. The Conversation x Cue interaction was also significant, $F(1, 34) = 10.03$, $p = .003$, $\eta_p^2 = 0.23$.

*Errors*

For the alerting network, a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Cue (Double vs No Cue) as factors showed that there was no main effect of Conversation, $F(1, 34) = 0.04$, $p = .85$, $\eta_p^2 = 0.001$, and no main effect of Cue, $F(1, 34) = 1.15$, $p = .29$, $\eta_p^2 = 0.03$. The Conversation x Cue interaction was non-significant, $F(1, 34) = 1.83$, $p = .19$, $\eta_p^2 = 0.05$. For the orienting network, a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Cue (Central vs Spatial) as factors showed that there was no main effect of Conversation, $F(1, 34) = 0.77$, $p = .39$, $\eta_p^2 = 0.02$. There was a main effect of Cue, $F(1, 34) = 5.32$, $p = .03$, $\eta_p^2 = 0.135$, in which there were more errors with the central cue than with the spatial cue. The Conversation x Cue interaction was non-significant, $F(1, 34) = 0.62$, $p = .44$, $\eta_p^2 = 0.02$. For the executive network, a within-participants ANOVA with Conversation (Conversation vs No Conversation) and Congruence (Congruent vs Incongruent) as factors showed that there was no main effect of Conversation, $F(1, 34) = 1.03$, $p = .32$, $\eta_p^2 = 0.03$. There was a main effect of Congruence, $F(1, 34) = 36.68$, $p = < .001$, $\eta_p^2 = 0.52$, in which there were more errors in the Incongruent than in the Congruent condition. The Conversation x Cue interaction was not significant, $F(1, 34) = 1.95$, $p = .17$, $\eta_p^2 = 0.05$. Overall, as none of the main effects of Conversation and none of its interactions, were significant, there was no evidence of a speed-accuracy trade-off.

## Discussion

The results of Experiment 2 replicated those of Experiment 1. Examining the effect of conversation on the ANT, we see that conversation had little effect on the alerting and orienting networks but again led to a decrease in the conflict effect in the executive network. That is, conflicting distractors interfered less with target responses when a conversation was being held. In the case of the ANT task, this led to an improved performance in target response. However, the larger implication of the results, suggest that the benefit to the ANT occurred because surrounding stimuli were not processed. The inability to attend to the surrounding environment has potential consequences for applied tasks like driving. We discuss this further in the General Discussion. Furthermore, there was an overall increase in response times in all of the Conversation conditions compared to the No conversation conditions. These latter results are consistent with the Cognitive Delay account proposed by Gunnell et al. (2020) and replicate those of Experiment 1. However, unlike in Experiment 1, there was no evidence of a speed-accuracy trade-off.

Examining the Backwards Digit Span condition, the results showed a large decrease in the conflict effect observed in the executive network. This is in line with perceptual load theory, whereby the increased resources needed to complete the Backwards Digit Span task, led to a reduction in the processing of distractor items. Interestingly the results also showed that the conflict effect was further reduced in the Backward Digit Span task in comparison to the Conversation condition. This suggests that there were fewer attentional resources available to process incongruent items in the Backward Digit Span condition compared to the Conversation condition. However, in comparison to the No Conversation condition, both the Backwards Digit Span and the Conversation task showed a reduced level of distractor processing.

Comparing the results between Experiments 1 and 2, we see that the effects for the alerting and orienting networks were comparable. However, there was a difference in conflict effects observed in the executive network, with smaller conflict effects in Experiment 1 compared to Experiment 2. This may be because the data for Experiment 2 were collected on-line, which, in itself, may have affected executive resources. It is for future research to investigate this further. However, importantly, for the purposes of our study the same pattern of results was found in both Experiments 1 and 2.

## General Discussion

This study examined the effect of conversation on the three independent networks responsible for attentional control. Across two experiments, the results showed that within all networks there was an overall delay in response when having a conversation compared to completing the task in silence. This finding is consistent with previous work in which conversation was found to cause a cognitive delay (Kunar et al., 2008; Kunar et al., 2018; Gunnell et al., 2020). However, of interest, the effect of conversation had *differential* effects on the alerting, orienting and executive conflict effects of the three attentional networks.

Examining the alerting network in both experiments, the results showed that there was no difference in the alerting effect when people were having a conversation versus when they were completing the task in silence. As the alerting network is thought to be responsible for vigilance, and that attending to abrupt onsets is considered an automatic process (Yantis & Jonides, 1984; Remington, Johnston, & Yantis, 1992; Theeuwes, 1994) it may come as no surprise that this network was not affected by conversation. The orienting network, likewise, was unaffected by conversation. In contrast a change was observed in the executive network, in which the conflict effect was reduced when participants were involved in a conversation. Please note that the reduction in the conflict effect due to conversation was not as severe as when participants were engaged in a more demanding 'executive' task (as observed in the Backwards Digit Span task used in Experiment 2). Nevertheless, in comparison to when completing the ANT in the no conversation condition, a substantial shift in executive performance was observed.

The executive network is considered to be involved in cognitive control and the ability to solve conflict (Fan et al., 2002). To determine executive use within the ANT the amount of distraction from incongruent distractors was calculated by subtracting congruent RTs from incongruent RTs. If we examine the executive results from Experiments 1 and 2: although RTs were higher in the Conversation condition, the conflict effects showed that there was *less* interference from the distractors when having a conversation than in the No conversation condition. As noted previously, this fits with a perceptual load account where, given the complexity of the conversation task, fewer attentional resources were available to process peripheral competing information (Lavie & Tsal, 1994 Lavie, 1995, Lavie, 2005). In the case of our experiments, filtering out the peripheral information (i.e., having fewer resources available for distractor processing) was beneficial for target response. However, in many tasks such filtering out of information could be disadvantageous. Take, for example, the process of driving. On the road there is typically a wide range of stimuli that is presented simultaneously. Depending on the driving situation, it may be beneficial to filter out some of these stimuli as distractions (e.g., billboard signs), however it is important to process others[8] (e.g., other vehicles, road signs). Given the dynamic nature of driving, some stimuli may suddenly change their status of being irrelevant to relevant (e.g. a pedestrian crossing the road, or a vehicle changing lane). When driving we will often not know in advance, which stimuli will become important to attend to ensure safety (for example, the processing of a visual advertisement will not contain important information for driving but information on a variable speed sign does). Other research has shown that drivers have failed to see road signs and traffic signals while talking on a mobile phone when driving (e.g., Strayer and Drews, 2007, Hancock et al., 2003). Failing to process this information has important implications for the safety of all road users. The present data extend this by showing that phone conversations affect our ability to effectively process information from the surrounding environment.

Although it is thought there are some minor interactions between the three attentional networks, they are largely considered to be independent functional architectures that utilise distinct neural

[8] Please note, our experiments did not test whether flanker items failed to be processed in the conversation condition, or whether they were processed and then subsequently inhibited. We believe the former is more likely, given that dual-tasks are known to deplete attentional resources needed to process other stimuli. However, further research would be needed to confirm this.

networks (Fan et al., 2002, Xiao et al., 2016). As noted in the introduction, Bergen et al. (2013) proposed that dual-task theories within the literature could be classified into two different domains: Domain General (e.g. akin to Capacity theories of attention, Kahneman, 1973) and Domain Specific (e.g. akin to Multiple Resource Theory, Wickens et al., 1984, 2002). The current work shows that when it comes to response times, conversation shows a dual-task interference effect consistent with Domain-General accounts. However, when it comes to the attentional control of each network, the results showed interference consistent with Domain-Specific theories, where the attentional cost of conversation is shown to specifically affect executive control. Both the alerting and orienting networks are associated with activation of the frontal and parietal areas of the cortex (Fan et al., 2002). However, executive control is largely associated with the frontal areas of the brain (such as the prefrontal cortex, Fan et al., 2002; Bush et al., 2000). Gunnell et al. (2020) found that CC and VM, both of which are associated with activation of the parietal areas are immune from the effects of conversation. It could be that mechanisms involving parietal attentional networks are exempt from the dual-task interference of conversation (apart from the cognitive delay in response times). However, it will be up to future research to confirm this.

Consistent with our findings, other tasks which have shown to be affected when conversing are also associated with executive control. For example, Strayer and Drews (2007) found that some tasks involving Working Memory, which are thought to be part of the executive function, are impaired when having a conversation (see also Hyman et al., 2009). The need for the executive is also thought to be highly important for safe driving behaviours (Pope et al., 2017)[9]. Research

[9] We do not want to limit the findings in this study to the applied situation of driving but given its direct applications and the growing problems as a result in the increase in mobile phone use (Glassbrenner, 2004) we believe it is an important area to discuss.

has shown greater activation of the frontal lobes when driving and there are correlational studies showing a link between teenagers who show atypical executive abilities and risky driving behaviour (Walshe et al., 2017). If the effect of conversation puts even greater strain on the executive, then this may lead to potentially riskier driving behaviour compared to when people are not in conversation. Walshe et al. (2017) have also highlighted the importance of the executive in driving and note the necessity to develop interventions and training for young adults given that this demographic group show a high level of injuries and fatalities when driving and are still showing maturation of their frontal lobes (see Gunnell et al., 2019, for an example of an effective driving intervention). We suggest that future driving interventions designed for young adults focus on how mobile phone conversations affect the executive, especially as young adults are thought to use their phones more than older adults while driving (Brusque & Alauzet, 2008).

Our results showed that conversations lead to delays in all three aspects of the ANT. Reaction times were longer overall in *all* network tasks when people were having a conversation, including the alerting tasks which are considered to be automatic. This slowing of response strengthens previous findings that have indicated a cognitive delay in the central attentional bottleneck and also has direct implications for driving. For example, taking the conversational delay observed in the alerting condition of Experiment 1, travelling at a speed of 60 miles per hour, would lead to a distance of approximately 5 feet being travelled, before response. If this were put into a driving situation, waiting to travel an extra five feet before braking could have serious consequences in an emergency. Previous research has documented that a delay in brake reaction times leads to an increase in both the likelihood of vehicle collisions and their severity (Brown, Lee and McGehee, 2001). Importantly, as alerting, orienting and executive reactions were all slowed this means responses to a number of stimuli within a driving task would all show a delay in being executed (e.g., alerting responses to a child running onto the road, orienting responses of processing a vehicle's indicator light and executive responses of selecting which stimuli are important to attend). In sum, the results in this paper add to the growing literature showing the impairments of having a conversation on a mobile phone. Moreover, the work brings understanding of how conversation impairs attention: both by an overall cognitive delay in response and specific changes to executive control. In particular, as mobile phone conversations compromise the executive and lead to generalised slowing, then it is all the more important that people take care to minimise this type of dual-task distraction when performing complex tasks like driving.

References


Alvarez, J. A. & Emory, E. (2006). Executive Function and the Frontal Lobes: A MetaAnalytic Review. *Neuropsychology Review 16(1):17-42.*

Beanland, V., Fitzharris, M., Young, K.L., Lenné, M.G., 2013. Driver inattention anddriver distraction in serious casualty crashes: data from the Australian NationalCrash In-depth Study. Accid. Anal. Prev. 54, 99–107.Begg, D

Bergen, B., Medeiros-Ward, N., Wheeler, K., Drews, F. A. & Strayer, D. L. (2013). The Crosstalk Hypothesis: Why Language Interferes With Driving. *Journal of Experimental Psychology: General, 142, 119-130.*

Berman, M. Jonides, J. & Kaplan, S. (2002), The Cognitive Benefits of Interacting With Nature, *Psychological Science, 19*, 1207 – 1212.

Brown, T. L., Lee, J. D., & McGehee, D. V. (2001). Human performance models and rear-end collision avoidance algorithms. *Human Factors, 43*, 462-482.

Brusque, C., & Alauzet, A. (2008). Analysis of the individual factors affecting mobile phone use while driving in France: Sociodemographic characteristics, car and phone use in professional and private contexts. *Accident Analysis & Prevention, 40*(1), 35-44.

Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in the anterior cingulate cortex. Trends in Cognitive Science, 4, 215–222.

Chun, M. M., & Jiang, Y. (1998). Contextual cueing: Implicit learning and memory of visual context guides spatial attention. *Cognitive Psychology, 36*(1), 28-71.

Cohen, J. (1988) Statistical Power Analysis for the Behavioural Sciences. New Jersey: Lawrence Erlbaum Associates

Conway, A. R., Cowan, N., & Bunting, M. F. (2001). The cocktail party phenomenon revisited: The importance of working memory capacity. *Psychonomic Bulletin & Review*, *8*(2), 331-335.

Corbetta, M. , Kincade, J. M. , Ollinger, J. M. , McAvoy, M. P. , & Shulman, G. L. (2000). Voluntary orienting is dissociated from target detection in human posterior parietal cortex. Nature Neuroscience, 3, 292–297.

De Fockert, J. W.; Rees, Geraint; Frith, Christopher D. and Lavie, Nilli. 2001. The role of working memory in visual selective attention. *Science, 291,* pp. 1803-1806.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a non-search task. *Perception & Psychophysics*, *16*, 143–149.

Eriksen, C. W. (1995). The flankers task and response competition: A useful tool for investigating a variety of cognitive problems. *Visual Cognition*, *2*(2-3), 101-118.

Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. *Neuroimage*, *26*(2), 471-479.

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.

Faul, F., Erdfelder, E., Lang, A.-G., & Buchner, A. (2007). G*Power 3: A flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behavior Research Methods, 39*, 175-191.

Giesbrecht, B, Sy, J. & Scott A. Guerin, S.A. (2013) Both memory and attention systems contribute to visual search for targets cued by implicitly learned context. *Vision Research, 85,* 80-89

Glassbrenner, D. (2005). *Driver Cell Phone Use in 2005--Overall Results* (No. HS-809 967). Washington D.C: NHTSA's National Center for Statistics and Analysis.

Grégoire, Jacques & Van der Linden, Martial. (1997). Effect of age on forward and backward digit spans. Aging Neuropsychology and Cognition - Aging Neuropsychol Cogn. 4. 140-149.

Gunnell, Daniel, Kunar, Melina A., Norman, Danielle and Watson, Derrick G. (2019) *The hazards of perception : evaluating a change blindness demonstration within a real-world driver education course. Cognitive Research: Principles and Implications, 4:15*.

Gunnell, D. O. A., Kunar, M. A., & Watson, D. G. (2020). Having a phone conversation delays but does not disrupt cognitive mechanisms. *Journal of Experimental Psychology: Applied*, *26*(2), 199–217. https://doi.org/10.1037/xap0000239

Hancock, P., Lesch, M., & Simmons, L. (2003). The distraction effects of phone use during a crucial driving maneuver, *Accident Analysis & Prevention, 35,* 501-514.

Horowitz, T. S., Klieger, S. B., Fencsik, D. E., Yang, K. K., Alvarez, G. A., & Wolfe, J.M. (2007). Tracking unique objects. *Perception & Psychophysics,* 69(2), 172-184

Humphreys, G.W., Kyllinsbæk, S., Watson, D.G., Olivers, C.N.L., Law, I. & Paulson, O. (2004) Parieto-occipital areas involved in efficient filtering in search: A time course analysis of visual marking using behavioural and functional imaging procedures. *Quarterly Journal of Experimental Psychology, 57A*, 610-635.

Hyman, I., Boss, S.M., Wise, B., McKenzie, K. & Caggiano, J. (2010).Did you see the unicycling clown? Inattentional blindness while walking and talking on a cell phone. *Applied Cognitive Psychology, 24*, 597-607.

Jarosz AF, Wiley J. (2014). What are the odds? A practical guide to computing and reporting bayes factors *Journal of Problem Solving*. 7: 2-9.

JASP Team (2021). JASP (Version 0.16) [Computer software].

Jeffreys, H. (1961). *Theory of probability* (3rd Ed.). Oxford, UK: Oxford University Press.

Jonides, J., & Yantis, S. (1988). Uniqueness of abrupt visual onset in capturing attention. *Perception & Psychophysics*, *43*(4), 346-354.

Kahneman, D. (1973). *Attention and effort.* Englewood Cliffs, NJ: Prentice Hall

Kray J, Karbach J, Haenig S, Freitag C. (2012) Can task-switching training enhance executive control functioning in children with attention deficit/-hyperactivity disorder? Front Hum Neurosci.; 5: 180

Kiesel A, Steinhauser M, Wendt M, et al. (2010) Control and interference in task switching - a review. Psychol Bull;136(5):849e74.

Kunar, M.A., Carter, R., Cohen, M. & Horowitz, T. (2008). Telephone Conversation Impairs Sustained Visual Attention Via a Central Bottleneck. *Psychonomic Bulletin & Review*, *15*, 1135-1140.

Kunar, M. A., Cole, L., Cox, A. & Ocampo, J. (2018). It is not good to talk: conversation has a fixed interference cost on attention regardless of difficulty, *Cognitive Research: Principles and Implications,* 3:33

Kunar, M. A., Flusberg, S. J., Horowitz, T. S., & Wolfe, J. M., (2007). Does contextual cueing guide the deployment of attention? *Journal of Experimental Psychology: Human Perception and Performance, 33,* 816-828.

Kunar, M.A., Gunnell, D., Richards, R., & Watson, D. (2022, February 16). Telephone Conversations Disrupt the Executive but not Alerting or Orienting Network. Retrieved from osf.io/6kvnb

Kunar, M. A., John, R. & Sweetman, H. (2014a). A Configural Dominant Account of Contextual Cueing: Configural Cues are Stronger than Colour Cues. *The Quarterly Journal of Experimental Psychology, 67,* 1366-1382.

Kunar, M. A., Watson, D. G., Cole, L. & Cox, A. (2014b). Negative Emotional Stimuli Reduce Contextual Cueing but not Response Times in Inefficient Search. *The Quarterly Journal of Experimental Psychology, 67*, 377-393.

Lavie, N. (1995). Perceptual load as a necessary condition for selective attention. *J. Exp. Psychol. Hum. Percept. Perform.* 21, 451–468.

Lavie, N. (2005). Distracted and confused?: Selective attention under load. *Trends Cogn. Sci.* 9, 75–82. doi: 10.1016/j.tics.2004.12.004

Lavie, N., and Tsal, Y. (1994). Perceptual load as a major determinant of the locus of selection in visual attention. *Percept. Psychophys.* 56, 183–197. doi: 10.3758/BF03213897

Levy, J., Pashler, H. & Boer, E. (2006). Central Interference in Driving: Is there any stopping the psychological refractory period?. *Psychological Science, 17(3),* 228-234.

Pashler, H. (1994). Dual-task interference in simple tasks: data and theory. *Psychological bulletin, 116*(2), 220-244.

Petersen, S. E., & Posner, M. I. (2012). The attention system of the human brain: 20 years after. *Annual Review of Neuroscience, 35*, 73.

Peirce, J. W., Gray, J. R., Simpson, S., MacAskill, M. R., Höchenberger, R., Sogo, H., Kastman, E., Lindeløv, J. (2019). PsychoPy2: experiments in behavior made easy. *Behavior Research Methods.* 10.3758/s13428-018-01193-y

Pope, C. N., Bell, T. R., & Stavrinos, D. (2017). Mechanisms behind distracted driving behavior: The role of age and executive function in the engagement of distracted driving. *Accident; analysis and prevention*, *98*, 123–129.

Posner, M. I. (2008). Measuring alertness. *Annals of the New York Academy of Sciences*, *1129*(1), 193-199.

Posner, M, I., & Petersen, S, E., (1990*)* The attention system of the human brain. *Annual Review of Neuroscience, 13,* 25–42.

Pylyshyn, Z. W., & Storm, R. W. (1988). Tracking multiple independent targets: evidence for a parallel tracking mechanism. *Spatial Vision, 3*(3), 179-197.

Remington, R. W., Johnston, J. C., & Yantis, S. (1992). Involuntary attentional capture by abrupt onsets. *Perception and Psychophysics, 51*(3), 279-290.

Sanbonmatsu, D. M., Strayer, D. L., Biondi, F., Behrends, A. A., & Moore, S. M. (2016). Cell-phone use diminishes self-awareness of impaired driving. *Psychonomic bulletin & review*, *23*(2), 617-623.

Sibly (2004). BlitzMax (Version 1.48) [Computer software].

Sisk CA, Remington RW, Jiang YV (2019). Mechanisms of contextual cueing: A tutorial review. *Attention, Perception, & Psychophysics, 81, 2571-2589.*

Strayer, D. L., & Drews, F. A. (2007). Cell-phone-induced driver distraction. *Current Directions in Psychological Science*, *16,* 128-131.

Strayer, D. L., Drews, F. A., & Crouch, D. J. (2006). A comparison of the cell phone driver and the drunk driver. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *48*(2), 381-391.

Strayer, D. L., & Johnston, W. A. (2001). Driven to distraction: Dual-task studies of simulated driving and conversing on a cellular telephone. *Psychological Science*, *12*(6), 462-466.

Tillman, G., Strayer, D., Eidels, A. *et al.* (2017) Modeling cognitive load effects of conversation between a passenger and driver. *Atten Percept Psychophys* **79,** 1795–1803.

Theeuwes, J. (1994). Stimulus-driven capture and attentional set: selective search for color and visual abrupt onsets. *Journal of Experimental Psychology: Human Perception and Performance*, *20*(4), 799-806.

Treisman, A. M., & Gelade, G. (1980). A feature-integration theory of attention. *Cognitive Psychology*, *12*(1), 97-136.

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, 58–76.

Walshe EA, Ward McIntosh C, Romer D, Winston FK. (2017) Executive function capacities, negative driving behavior and crashes in young drivers. Int J Environ Res Public Health. ;14(11):1314.

Watson, D. G., & Humphreys, G. W. (1997). Visual marking: prioritizing selection for new objects by top-down attentional inhibition of old objects. *Psychological Review*, *104*(1), 90-122.

Watson, D. G. & Kunar, M. A. (2010). Visual marking and change blindness: Moving occluders and transient masks neutralize shape changes to ignored objects. *Journal of Experimental Psychology: Human Perception and Performance, 36,* 1391-1405.

Watson, D. G. & Kunar, M. A. (2012). Visual Marking: Determining the capacity of time-based selection. *Journal of Experimental Psychology: Human Perception and Performance, 38,* 350-366.

Weaver, B., Bédard, M., McAuliffe, J. & Parkkari, M. (2009) Using the attention network test to predict driving test scores. *Accident Analysis & Prevention, 41* (1) 76-83.

Welford, A. T. (1952). The ‘‘Psychological Refractory Period’’ and the Timing of High-Speed Performance - A review and a Theory. *British Journal of Psychology,* 43, 2–19.

Wolfe, J. M., Place, S. S., & Horowitz, T. S. (2007). Multiple Object Juggling: Changing what is tracked during extended multiple object tracking. *Psychonomic Bulletin & Review, 14*(2), 344-349.

Xiao M., Ge H., Khundrakpam B.S., Xu J., Bezgin G., Leng Y., Zhao L., Tang Y., Ge X., Jeon S. (2016) Attention performance measured by attention network test is correlated with global and regional efficiency of structural brain networks. Front. Behav. Neurosci.; 10:194.

Yantis, S., & Jonides, J. (1984). Abrupt visual onsets and selective attention: evidence from visual search. *Journal of experimental psychology. Human Perception and Performance*, *10*(5), 601-621.

*Table 1: Mean correct RTs (ms) for each condition in Experiment 1 (standard errors are in parentheses).*

| | **Conversation** | **No Conversation** |
|---|---|---|
| Alerting – No Cue | 567.3 (11.3) | 513.5 (9.7) |
| Alerting – Double Cue | 522.9 (9.8) | 470.3 (8.3) |
| Orienting – Centre Cue | 528.2 (11.5) | 474.1 (8.4) |
| Orienting – Spatial Cue | 504.3 (10.0) | 453.7 (8.7) |
| Executive – Incongruent | 564.3 (10.4) | 524.4 (9.5) |
| Executive - Congruent | 513.7 (10.3) | 456.6 (8.9) |
| Executive - Neutral | 514.95 (10.9) | 454.2 (8.0) |

*Table 2: Mean Errors (%) for each condition in Experiment 1 (standard errors are in parentheses).*

| | **Conversation** | **No Conversation** |
|---|---|---|
| Alerting – No Cue | 0.8 (0.2) | 1.6 (0.4) |
| Alerting – Double Cue | 1.3 (0.2) | 1.7 (0.4) |
| Orienting – Centre Cue | 1.3 (0.2) | 1.9 (0.3) |
| Orienting – Spatial Cue | 0.9 (0.3) | 1.3 (0.3) |
| Executive – Incongruent | 2.3 (0.4) | 3.5 (0.5) |
| Executive - Congruent | 0.4 (0.1) | 0.7 (0.2) |
| Executive - Neutral | 0.4 (0.1) | 0.7 (0.2) |

*Table 3: Mean correct RTs (ms) for each condition in Experiment 2 (standard errors are in parentheses).*

| | **Conversation** | **No Conversation** | **Backwards Digit Span** |
|---|---|---|---|
| Alerting – No Cue | 675.9 (16.1) | 612.6 (13.4) | 719.5 (13.8) |
| Alerting – Double Cue | 641.7 (14.7) | 592.1 (14.3) | 688.8 (12.1) |
| Orienting – Centre Cue | 650.1 (13.4) | 591.5 (13.0) | 706.9 (13.7) |
| Orienting – Spatial Cue | 644.6 (15.8) | 575.3 (13.2) | 682.4 (15.0) |
| Executive – Incongruent | 740.5 (17.9) | 695.8 (18.7) | 771.5 (14.0) |
| Executive - Congruent | 606.4 (14.2) | 537.4 (10.9) | 666.6 (13.3) |
| Executive - Neutral | 623.8 (15.7) | 563.5 (14.7) | 672.8 (15.0) |

*Table 4: Mean Errors (%) for each condition in Experiment 2 (standard errors are in parentheses).*

| | **Conversation** | **No Conversation** | **Backwards Digit Span** |
|---|---|---|---|
| Alerting – No Cue | 4.3 (1.0) | 4.0 (1.0) | 8.6 (1.9) |
| Alerting – Double Cue | 4.2 (0.8) | 4.8 (1.0) | 7.6 (1.5) |
| Orienting – Centre Cue | 4.9 (1.1) | 5.8 (1.3) | 7.6 (1.9) |
| Orienting – Spatial Cue | 4.1 (1.0) | 4.4 (1.0) | 8.9 (1.8) |
| Executive – Incongruent | 9.8 (1.6) | 12.1 (2.3) | 16.5 (3.0) |
| Executive - Congruent | 0.9 (0.4) | 0.5 (0.2) | 3.4 (1.0) |
| Executive - Neutral | 2.8 (1.6) | 1.8 (1.2) | 5.0 (1.7) |

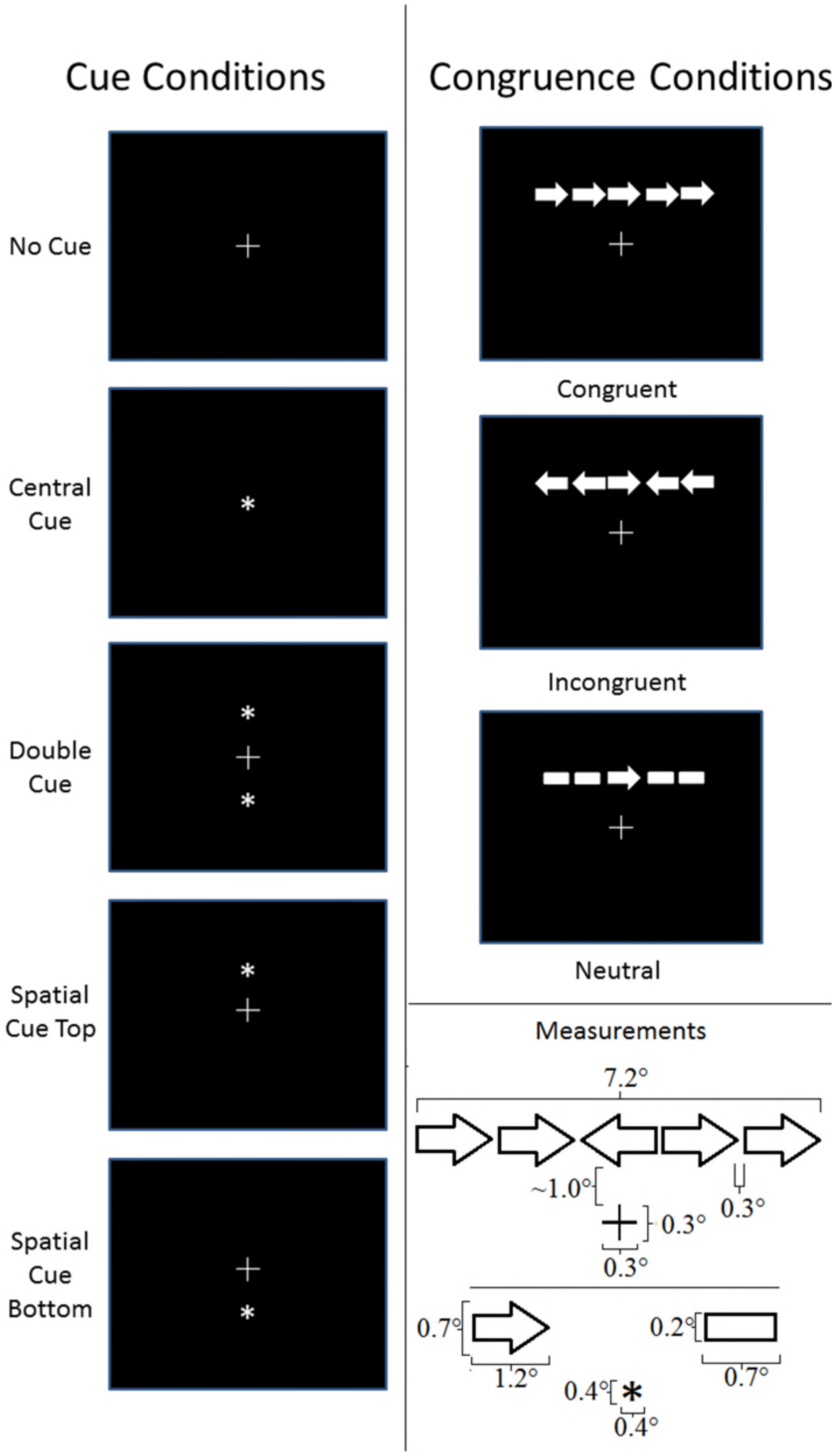
# Figures

Figure 1. The individual cue conditions and congruence conditions for each of the ANT networks. Stimuli measurements are given in visual degrees.

Figure 2. An example trial. The first display is presented for a random duration between 400 and 1600ms, so that the targets appearance is not temporally predictable from the beginning of the trial. The participant’s RT is naturally variable. Therefore, the final display duration is calculated by taking the sum of the durations for all previous displays away from 4000ms. This ensures that each trials duration is equal to 4000ms.

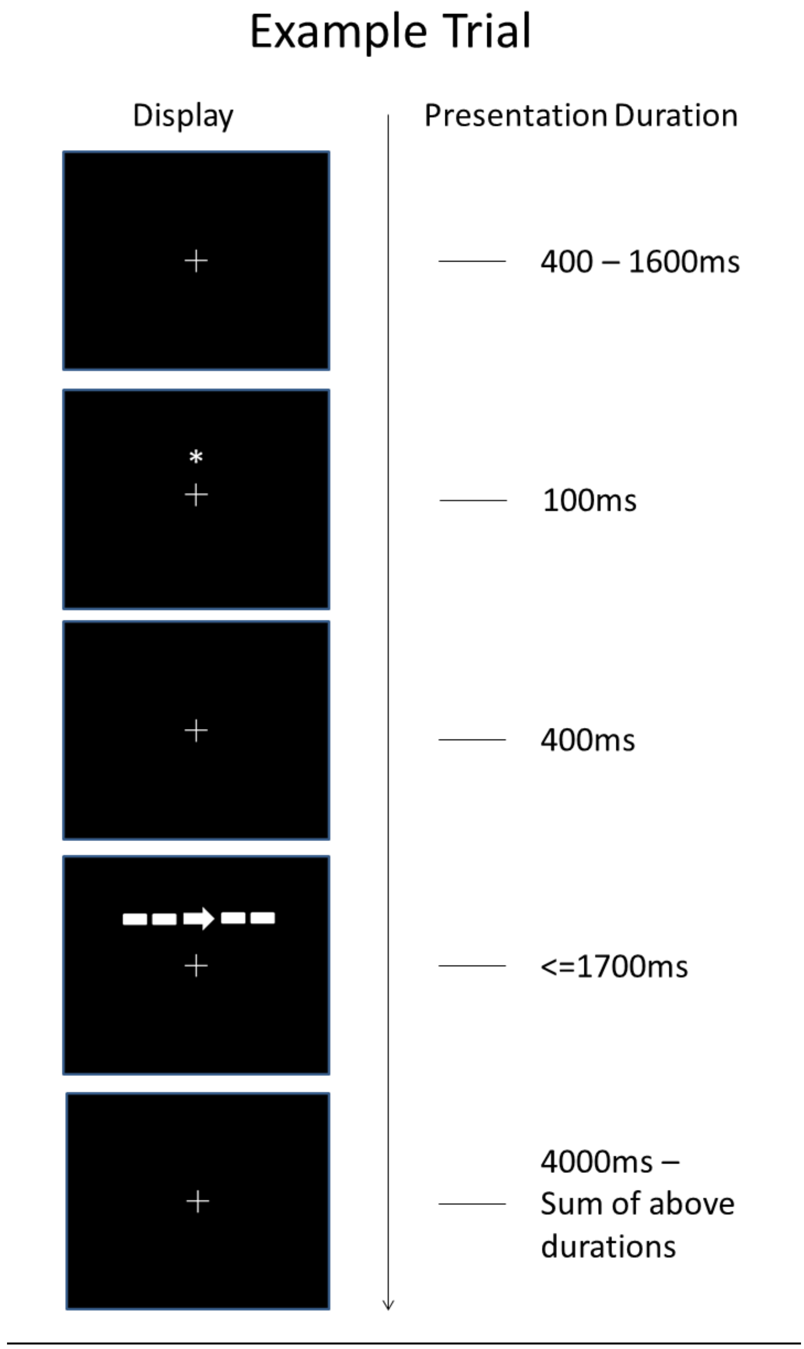
Figure 3. The mean network effect of each attentional network in milliseconds as a function of conversation in Experiment 1. The network effects indicate the alerting, orienting and conflict effect for the Alerting, Orienting and Executive network, respectively. Error bars represent the standard error.

Figure 4. The mean network effect of each attentional network in milliseconds as a function of condition in Experiment 2. The network effects indicate the alerting, orienting and conflict effect for the Alerting, Orienting and Executive network, respectively. Error bars represent the standard error.



Cue Conditions
Congruence Conditions
No Cue
Central Cue
Double Cue
Spatial Cue Top
Spatial Cue Bottom
Congruent
Incongruent
Neutral
Measurements
7.2°
~1.0°
0.3°
0.3°
0.3°
0.7°
1.2°
0.2°
0.7°
0.4°
0.4°


Figure 1.



Example Trial
Display
Presentation Duration
400 – 1600ms
*
100ms
400ms
<=1700ms
4000ms –
Sum of above
durations


Figure 2.

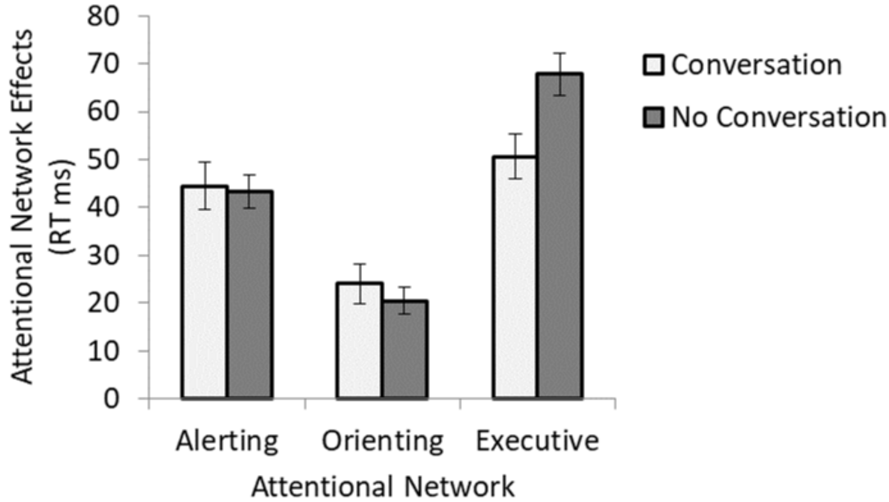

80
70
60
50
40
30
20
10
0
Attentional Network Effects (RT ms)
Conversation
No Conversation
Alerting
Orienting
Executive
Attentional Network

Figure 3.

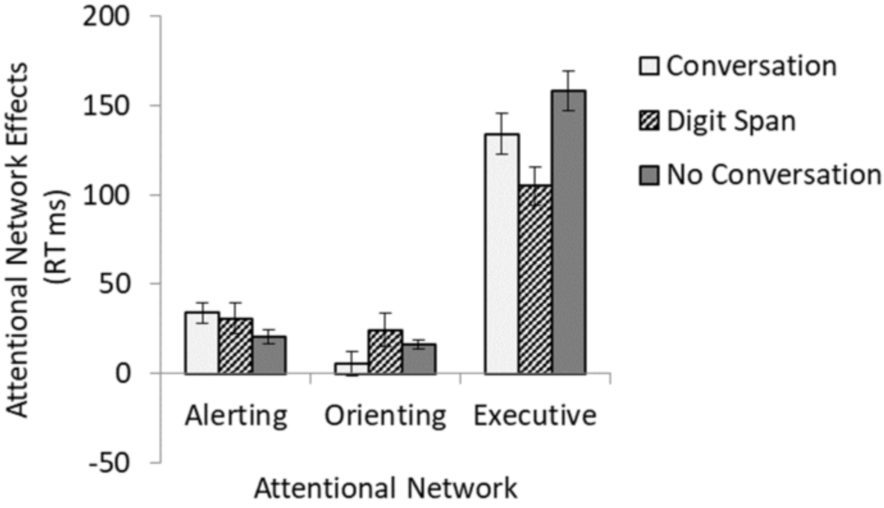

200
150
100
50
0
-50
Attentional Network Effects (RT ms)
Alerting
Orienting
Executive
Attentional Network
Conversation
Digit Span
No Conversation

Figure 4.