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Repeated measurement of the components of attention using two versions of the Attention Network Test (ANT): Stability, isolability, robustness, and reliability

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ABSTRACT

Using orthogonal subtractions of performance in selected conditions the attentional network test (ANT) measures the efficacy of three isolable components of attention: alerting, orienting, and executive control. Ten test sessions, each containing two versions of the ANT (Fan et al., 2002; Callejas et al., 2005), were administered to 10 young adults to examine stability, isolability, robustness, and reliability of the tests. Participants indicated the direction of a target arrow presented either above or below the fixation. The target arrow was accompanied by distracting arrows, either pointing to the same direction (congruent) as or the opposite direction (incongruent) to the target arrow. The arrows were preceded by informative visual cues (central, double, spatial, and no cue) differing in temporal and spatial information (Fan et al.) or by alerting auditory signals (tone and no tone) and uninformative visual cues (valid, invalid, and no cue) (Callejas et al.). All network scores remained highly significant even after nine previous sessions despite some practice effects in the executive and the orienting networks. Some lack of independence among the networks was found. The relatively poor reliability of network scores with one session of data rises to respectable levels as more data is added.

1. Introduction

The original Attention Network Test (which we will refer to it simply as 'ANT') was developed by Fan et al. (2002) to measure three isolable attentional networks: alerting, orienting, and executive attention. These networks are defined jointly in anatomical and functional terms, by finding correspondence between areas of activation in the brain and performance in attention tasks which measure different functions of attention. Alerting involves a change in mental state as well as some changes in physiological state. These changes follow the presentation of a signal that provides information that a task-relevant event will occur soon (Posner, 1978). Right hemisphere and thalamic areas are involved in alerting (e.g., Coull et al., 1996; Sturm and Willmes, 2001). Orienting involves turning one's attention to a source of signals in space (Posner, 1978). Areas of the parietal lobe, the midbrain, and the thalamus have been associated with this function (Posner and Raichle, 1994). Executive attention involves conflict resolution and control over decision-making, error detection, and habitual response inhibition (Norman and Shallice, 1986). The anterior cingulate cortex and the lateral prefrontal cortex have been associated with this function (e.g., Bush et al., 2000; Casey et al., 2000).

The ANT is a simple, yet carefully designed, test of performance in which specific subtraction scores are used to measure the efficiency of three different attention networks (Klein, 2003). On each trial, different types of warning cue precede a central target arrow, pointing either left or right, that is often flanked by distracting arrows (Fig. 1A). The participants' task is to indicate the direction of the target arrow as quickly and accurately as possible. The efficiency of the alerting and orienting networks are measured by comparing performance in the different types of cue condition (central, double, spatial, and no cues); the efficiency of the executive network is measured comparing performance in the different types of target congruency condition (congruent and incongruent) (Table 1). Fan et al. (2002) demonstrated that the ANT provides a reliable measure of each network (alerting, orienting and executive attention). In addition, they suggested that each network was independent of the others by showing no significant correlations among the network scores. However, they also reported an interaction between the cue condition and target congruency (as have others, see e.g., Ishigami and Klein, 2009), suggesting some lack of independence among the networks. It is partly for this reason that we use the weaker term (from Posner, 1978) "isolable" when describing relationships among the three attention networks.

As noted by Callejas et al. (2005) there are limitations of the ANT as described above. First, the alerting and the orienting networks are both defined by cue condition (i.e., alerting = double cue minus no cue conditions, orienting = center cue minus spatial cue conditions). Consequently, we cannot know whether the alerting and

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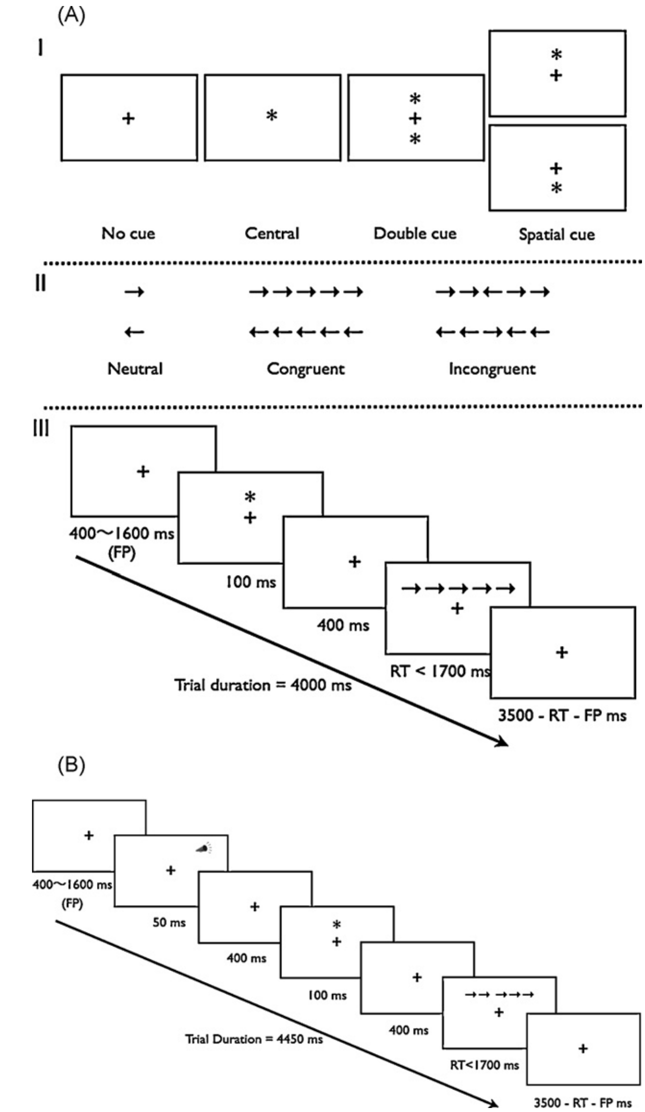

Fig. 1. (A) Experimental procedure of the ANT (Fan et al., 2002). (I) The four cue conditions. (II) The six stimuli used in the present experiment and (III) an example of the procedure; a spatial cue is presented followed by a target (central) arrow. (B) Experimental procedure of the ANT-I (Callejas et al., 2005). An example of the procedure; an auditory tone is presented, followed by a valid cue, and a target (central) arrow flanked by congruent arrows.

Table 1
Conditions and their levels in the ANT and the ANT-I.

	ANT	ANT-I
Auditory signal	NA	Tone No tone
Cue condition (ANT), visual cue (ANT-I)	No cue Central cue Double cue Spatial	No cue Valid Invalid
Target congruency	Neutral Congruent Incongruent	Congruent Incongruent
Subtractions for each network		
Alerting	No cue–double cue	No tone–tone
Orienting	Central cue–spatial cue	Invalid–valid
Executive	Incongruent–congruent	Incongruent–congruent

the orienting networks interact. Relatedly, we cannot separate a potential interaction between the alerting and orienting networks from the significant interaction between cue condition and target congruency, which Fan et al. (2002) reported. Second, their peripheral cue (spatial cue condition), one of the two cue conditions used to define the orienting network, predicts the target location with 100% validity. The combination of information value with peripheral cueing means that the measure of orienting (central minus peripheral cue) has indeterminate contributions from exogenous and endogenous shifts of attention (Klein, 2004). In the model cueing task developed by Posner and colleagues (e.g. Posner, 1980; see Klein, 2005, for a review) orienting is measured as the difference in performance following a peripheral (or central arrow) cue between targets presented at the cued location versus targets presented at the opposite, uncued location. Importantly, in both of these conditions the participant's attention is in the same general state (captured by a peripheral cue or allocated in response to the central arrow cue) regardless of where the target is presented. Mental state is necessarily different with the use of a cue with 100% validity, which is compared to a neutral cue to generate a subtraction score (see Jonides and Mack, 1984, for a discussion of this problem).

Callejas et al. (2005) developed an alternative version of the ANT [we will refer to it as the Attention Network Test-Interactions (ANT-I)] to overcome these limitations (Fig. 1B, Table 1). As with the ANT, the orienting and executive networks are defined by the visual cue (valid and invalid) and target congruency (congruent and incongruent), respectively. However, the alerting network is defined by auditory signals (tone and no tone). The separation of the alerting (auditory) from the orienting (visual) cues permits the researcher using this task to explore performance as a joint function of orienting (valid vs invalid) and alerting (tone vs no tone). A secondary benefit of this change derives from the possibility that auditory signals have greater alerting effects than visual signals (Posner, 1978; Posner et al., 1976). Thus, this design permits the researcher to examine the interaction among the networks with confidence. In addition, uninformative peripheral cues were used to define the orienting network in the ANT-I. The use of uninformative peripheral cues allows the researcher to measure the effect of exogenous orienting while excluding the endogenous component. Callejas et al. reported statistical interactions among all the networks. The executive network is inhibited by the alerting network (see also Posner, 1994), but facilitated by the orienting network (see also Funes et al., 2007). In addition, the orienting network is facilitated by the alerting network especially when stimulus onset asynchrony (SOA) is short (i.e., 100 ms rather than 500 ms, which is used in the current study) (see also Sturm et al., 2006; Thimm et al., 2006). Thus, Callejas et al. concluded that the attentional networks in the ANT operate interactively.

Both versions of the ANT (i.e., the ANT and the ANT-I) provide convenient measures of attentional networks (alerting, orienting, and executive attention). It takes only about 20 min to complete, and it is easily performed by children, older adults, brain damaged patients, and even monkeys (e.g., Beran et al., 2003; Jennings et al., 2007; Rueda et al., 2004). Thus, it can be used in variety of contexts (e.g., clinical, genetic, etc.) to address a wide range questions about attention. Indeed, since the original version of the ANT was introduced by Fan et al. (2002) versions of the test have been used in over 60 publications dealing with a wide range of topics and methods including: development, neuroimaging, pharmacology, genetics, psychiatric disorders, brain damage, individual differences, etc. One class of situation to which the ANT might be applied are those in which repeated testing is required. For example, Tang et al. (2007) examined effects of meditation training on alerting, orienting, and executive function (see also Jha et al., 2007). Eighty university students were randomly assigned to either an