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Introversion and working memory: central executive differences

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Abstract

The relationship between introversion and working memory was tested. Prior studies have either not focused directly on working memory or have focused only on the storage component of working memory. Neuroanatomical and neurochemical relationships between dorsolateral prefrontal cortex and the reticular formation suggest that the executive component of working memory is the most likely to differ across introverts and extraverts. Using Sternberg's [Sternberg, S. (1975). Memory scanning: new findings and current controversies. *Quarterly Journal of Experimental Psychology*, *27*, 1–32.] memory scanning paradigm, which taps the central executive component of working memory, results indicate that introverts are slower than extraverts in comparing the contents of working memory to an external target. Social psychological consequences of this central executive difference in working memory are discussed.

1. Introduction

Over the past half century, arousal accounts have dominated explanations of the differences between introverts and extraverts (Eysenck, 1967; Humphreys & Revelle, 1984). Because arousal is a noncognitive variable, it has been difficult for cognitive psychologists to bridge levels of analysis in attempting to understand the relation between the cognitive and the psychophysiological profiles of extraversion. Differences in neurochemistry and neuroanatomy are generally far more amenable to modular or neural circuitry-based views of cognition. The reticular formation in the brainstem, long cited as the anatomical source of arousal differences associated with extraversion (Eysenck, 1967), has recently been shown to exert control

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upstream over certain cortical and subcortical areas of the brain. Specifically, the pontine reticular nucleus projects to both the prefrontal cortex and the basal ganglia modulating the release of dopamine (DA; Martin, 1996; Robbins & Everitt, 1995). Each of these areas is central to higher cognitive functions. Dorsolateral prefrontal cortex (DLPFC) is involved in working memory (Cabeza & Nyberg, 1997), while the basal ganglia is central to procedural memory formation (Lieberman, in press; Saint-Cyr & Taylor, 1992). Furthermore, both DLPFC and basal ganglia depend on DA for normal functioning (Cohen & Servan-Schreiber, 1992; Spitzer, 1993; Wickens & Kotter, 1995). These advances in mapping the neuroanatomical and neurochemical links from the reticular formation to other areas of the brain offer new avenues of insight into the cognitive consequences of arousal differences. Based on these findings, it should be expected that extraverts and introverts would differ both in their working memory and their procedural memory.

The expected difference in procedural memory has been found by Corr and colleagues (Corr, Pickering & Gray, 1995). In this study, subjects identified as quickly as possible, in which of four quadrants a target appeared. On 40% of the trials, a rule determined the location of the target and thus the location could be predicted, though only implicitly on the basis of procedural memory (Lewicki, Hill & Bizot, 1988). Introverts demonstrated a higher degree of procedural learning. This is consonant with Fischer, Wik and Fredrikson's (1997) findings, using positron emission tomography, of greater subcortical activation in the basal ganglia of introverts than extraverts.

2. Introversion and working memory

The relationship of introversion and working memory has been nearly studied, or confounded with the investigation of other variables, a number of times. Only three experiments have directly assessed this relation. The unfortunate confound in most of the studies results from the historical progression of memory research. In the 1960s and 1970s, memory was conceptualized in terms of short- and long-term memory. Long-term memory denoted demonstration of memory after a retention interval of 10–20 minutes. Short-term memory was tested using any shorter retention interval. Working memory was not directly studied in this context.

The predominant memory probe used to investigate the relationship between extraversion and memory was paired-associates list learning. Subjects in these experiments learned pairs of words with one member of each pair later being used as a retrieval cue for the other. Howarth and Eysenck (1968) tested extraverts and introverts using seven pairs of associates with retention intervals of 0 min, 1 min, 5 min, 30 min and 1 day. The immediate recall condition is the most likely to bear on the relationship between introversion and working memory. In this condition, extraverts remembered nearly twice as many associates as introverts. Osborne (1972) performed a similar experiment and found that with a 2.5 min retention interval, low arousal subjects (extraverts) outperformed high arousal subjects (introverts). Unfortunately, such tests do not parse out successful memorization from actively maintaining the pairs in working memory.

A few studies (Howarth, 1969; Bone, 1971) incorporated the notion of *response competition* into the paired-associates paradigm. Participants in these studies were required to inhibit responding with pre-existing associates of the retrieval cue words. Thus, these participants were using working memory in a more active or dynamical way, in the sense that they were simultaneously searching for a correct target word and attempting to inhibit the tendency to respond with an intrusive prepotent associate.

Howarth (1969) had subjects learn to associate each word on list A with a word on list B. After learning the associations to criterion, list B was reordered so that words on list A became associated with different words on list B. Finally, after this second set of associations was learned, list B was reordered yet again. On the third set of trials, when the stimulus from list A was given, there were three different words from list B associated with responding. Extraverts required fewer trials to reach criterion, *but only on the third set* when response competition was greatest. This suggests that extraverts are better at inhibiting prior dominant responses that are errors in the current context, which is a function associated with the prefrontal cortex.

Following up on Howarth, Bone (1971) performed a more ecologically valid study of response competition. Introverts and extraverts each learned one of two lists of paired associates. In one condition, subjects learned paired-associates that were generated by intermixing pairs of natural associates known to have strong associations in the average person. Thus, each word was more strongly associated with a different word on the list than its current paired-associate. In the second condition, the list contained no cross-pairs with pre-existing associations. Introverts made more errors than extroverts in the course of reaching the criterion for learning, but *only for the list that consisted of re-ordered preexisting associates*.

Gabrys, Schumph and Utendale (1987) and Jensen (1962) were closer to the mark in terms of investigating working memory capacity and extraversion. Gabrys et al. (1987) had subjects read two stories each containing 21 episodic details that the subjects were to recall immediately after completion of each story. Recall was linearly associated with extraversion. Jensen (1962) used a serial learning task to examine personality differences in memory performance. Nine shapes were presented in a fixed order until subjects were able to predict each shape before its presentation. The shapes were either presented with a duration of two or four seconds per slide. In the condition with greater time pressure, introverts made more errors than extraverts, though not significantly so ($P < 0.16$).

Three experiments have looked at working memory capacity differences using a traditional measure, the digit span task. In the digit span task, subjects hold a digit string in memory and then repeat it. The digit span refers to the number of digits in the longest string that is accurately repeated. Two studies found no differences in span between introverts and extraverts (Howarth, 1963; Lieberman & Rosenthal, submitted), while Tanwar and Malhotra (1992) found a significant difference.

Baddeley (1986) proposed that working memory consists of three subsystems: the central executive system, the phonological loop and the visuospatial sketchpad. The central executive is thought to be located in DLPFC and is involved in the monitoring of the contents of the other two systems as well as using the contents of these storage systems to make comparisons with external stimuli (Cabeza & Nyberg, 1997; Petrides et al., 1993a; Haxby et al., 1995). The phonological loop and visuospatial sketchpad are storage systems located in the parietal lobe that hold the contents of working memory on line (Cabeza & Nyberg, 1997; Petrides et al., 1993a, b; Paulesu, Frith & Frackowiak, 1993). Given that the reticular formation impacts

DLPFC but not the parietal lobe, it is reasonable to expect introverts and extraverts to differ most strongly on working memory tasks tapping the central executive by requiring active comparisons between working memory and external targets. Digit span is thought to rely very little on the dynamical processes of the central executive (O'Reilly, Braver & Cohen, 1997) and thus may not be the best choice of tasks. In the current experiment, Sternberg's (1975) memory scanning paradigm was used as the task involves scanning the phonological store and comparing each item to the externally presented target thus relying on the central executive.

The results of the prior studies of working memory suggest that to the extent that central executive differences exist between introverts and extraverts, we should expect extraverts to be the beneficiaries. Why should this be the case? The more active ascending reticular activating system of introverts should lead to greater production of DA and thus higher levels of this neurotransmitter in both DLPFC and basal ganglia (Fischer et al., 1997). Recent primate cognition research suggests that there is a narrow range of optimal DA innervation of PFC, with greater amounts functioning to impair PFC performance (Arnsten & Goldman-Rakic, 1998). Thus, it may be the case that for extraverts, the presence of DA in the PFC resides in this narrow optimal range, while for introverts there is an overabundance of DA in PFC leading to poorer central executive functioning.

3. Method

3.1. Subjects

Twenty-eight individuals (Mean age = 20.3 years) completed the Eysenck Personality Inventory scale for extraversion (Eysenck & Eysenck, 1968). The seven most extraverted ($M_{EPI} = 15.78$) and the seven most introverted ($M_{EPI} = 9.98$) individuals were brought in to complete the rest of the experiment. Data for one subject was lost due to a computer error. Thus, the final sample used was 10 females and 3 males. Ss were recruited from an introductory psychology course and received class credit for their participation.

3.2. Memory scanning task

The task is nearly identical to that reported by Sternberg (1975). The task was composed of two practice blocks of 10 trials each and 12 test blocks of 20 trials each. Each block began with the presentation of the memory set. The memory set was a set of one to six digits that were to be held in memory during a given block of trials. The memory set digits were presented at a rate of one per second. Once the test trials began, targets were presented one at a time. Subjects were required to respond as quickly as possible, while maintaining accuracy, whether or not the target was a member of the memory set. After each response, there was a two second inter-trial interval and then the next target was presented. After the block of trials was completed, a new memory set was presented and the process repeated.

Subjects had each memory set size from one to six for two different blocks. The order of the blocks was pseudo-random. The first occasion of each memory set size was constrained to occur in the first six blocks, while the second occasion occurred in the last six blocks.

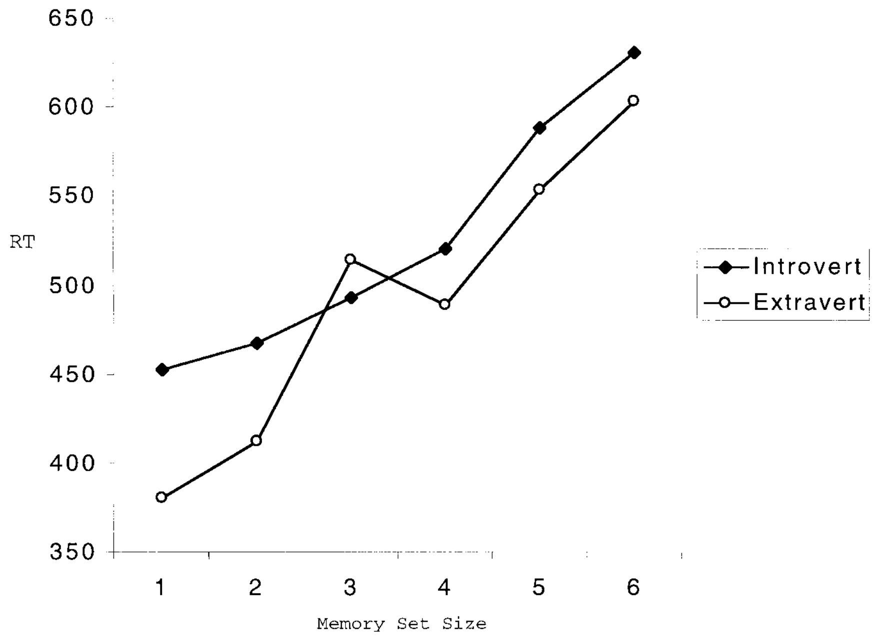

Fig. 1. Performance on the Sternberg memory scanning task as a function of memory set size for introverts and extraverts.

4. Results

The best fitting line for each subject's reaction times was found by regressing each subject's reaction times on memory set size. The y-intercepts associated with each subject's line were compared revealing faster reaction times for extraverts than introverts, $t(11) = 2.28$, $P < 0.05$, $r = -0.57$ ($M_{Extravert} = 341.19$ ms, $SEM_{Extravert} = 15.11$ ms; $M_{Introvert} = 397.28$ ms, $SEM_{Introvert} = 19.97$ ms). As seen in Fig. 1, this difference is carried disproportionately by the two smallest memory set sizes, but is apparent in all but memory set size three. The correlations between extraversion and reaction time in each set size are shown in Table 1. That five of the six

Table 1
Correlations between extraversion and average reaction time in each memory set size

	Extraversion	P-value	
Memory Set Size	1	−0.61	0.03
	2	−0.55	0.06
	3	+0.15	NS
	4	−0.23	NS
	5	−0.17	NS
	6	−0.16	NS
Y-intercept		−0.57	0.05

correlations are in the same direction is marginally significant based on a sign test, $P < 0.07$. Additionally, for memory set sizes one, $t(11) = 2.54$, $P < 0.03$, and two, $t(11) = 2.19$, $P < 0.06$, extraverts had reliably faster mean reaction times than introverts.

5. Discussion

The results of the current study suggest that extraverts have better working memory skills than introverts. Furthermore, because the Sternberg paradigm (1975) was used, it is reasonable to conclude that the advantage is specifically located within the central executive component of working memory. This fits well with neuroscientific theories of working memory and the known neuroanatomical differences between introverts and extraverts. The central executive component of working memory is thought to be located largely in DLPFC which, in turn, is influenced by the reticular formation which, in turn, has been associated with differences in introverts and extraverts.

Though extraversion was arguably a social psychological dimension originally, few of the cognitive and biological findings have been used in conjunction with or in an attempt to further our understanding of the social dimension of extraversion. Differences in working memory have clear consequences for the social psychology of introverts and extraverts. O'Reilly et al. (1997) suggest that task goals and contextual information relevant for goal completion are instantiated neurally in the DLPFC. Furthermore, they suggest that only a few goal representations can be active at once. Lieberman and Rosenthal (submitted) have found that when two interpersonal goals are relevant, extraverts are better able than introverts to maintain and carry out both goals. Introverts showed normal performance on their primary goal, but were impaired on their secondary goal.

Within the social cognitive literature, Gilbert (Gilbert, 1989; Gilbert & Hixon, 1991; Gilbert, Krull & Pelham, 1988) has introduced the notion of cognitive busyness which refers to effects on task A when working memory is being used to complete task B. Cognitive busyness is usually manipulated by requiring subjects to count tones or rehearse lengthy digit strings while engaging in some social psychological judgment. The current data suggests that introverts may be thought of as trait cognitively busy. Cognitive busyness has consequences across different domains of social psychology including attribution (Gilbert et al., 1988), stereotyping (Gilbert & Hixon, 1991; Gordon & Anderson, 1995; Macrae, Milne & Bodenhausen, 1994), attitude-behavior consistency (Blessum, Lord & Sia, 1998) and persuasion (Buller, 1986). Based on the current findings of working memory differences in introverts and extraverts, future research ought to assess the extent to which introverts naturally respond the way that cognitively busy subjects have been found to respond.

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