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Impairments in proverb interpretation following focal frontal lobe lesions ☆

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ABSTRACT

The proverb interpretation task (PIT) is often used in clinical settings to evaluate frontal "executive" dysfunction. However, only a relatively small number of studies have investigated the relationship between frontal lobe lesions and performance on the PIT. We compared 52 patients with unselected focal frontal lobe lesions with 52 closely matched healthy controls on a proverb interpretation task. Participants also completed a battery of neuropsychological tests, including a fluid intelligence task (Raven's Advanced Progressive Matrices). Lesions were firstly analysed according to a standard left/right sub-division. Secondly, a finer-grained analysis compared the performance of patients with medial, left lateral and right lateral lesions with healthy controls. Thirdly, a contrast of specific frontal subgroups compared the performance of patients with medial lesions with patients with lateral frontal lesions. The results showed that patients with left frontal lesions were significantly impaired on the PIT, while in patients with right frontal lesions the impairments approached significance. Medial frontal patients were the only frontal subgroup impaired on the PIT, relative to healthy controls and lateral frontal patients. Interestingly, an error analysis indicated that a significantly higher number of concrete responses were found in the left lateral subgroup compared to healthy controls. We found no correlation between scores on the PIT and on the fluid intelligence task. Overall our results suggest that specific regions of the frontal lobes contribute to the performance on the PIT.

1. Introduction

1.1. Abstraction and the frontal lobes

The selective impairment of abstract thought processes as a result of neurological disease has long been known of; at least since such an impairment was held to reflect the loss of an *abstract attitude* (Goldstein, 1936, 1944). More specifically, it has been associated with lesions to the frontal cortex. Thus, Luria (1966, p. 285) concluded that the difficulties of frontal patients with abstraction emerged from their "lapse into irrelevant connections" when constructing abstract mental representations. As far as specific experimental results are concerned, Cicerone, Lazar, and Shapiro (1983) reported an abstract thought impairment in a group of frontal lobe patients who were shown to be unable to generate hypotheses regarding the underlying patterns in a visual learning task. Other studies showed that frontal lobe damage led to difficulties in abstracting rules in temporal and spatial patterns (Burgess & Shallice, 1996; Reverberi, Lavaroni, Gigli, Skrap, & Shallice, 2005; Villa, Gainotti, De Bonis, & Marra, 1990). More recently, using functional imaging, increased cerebral activity has been observed in prefrontal areas alongside increased "chunking" of specific visual sequences into abstract shapes during a spatial memory task (Bor, Duncan, Wiseman, & Owen, 2003).

Analogical reasoning is a further aspect of abstract reasoning that has also implicated the prefrontal cortex. In the non-verbal domain, fMRI studies have shown increased PFC activation when

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assessing the relationships between pairs of visual stimuli (Bunge, Helskog, & Wendelken, 2009; Krawczyk, Michelle McClelland, & Donovan, 2011), when deriving and applying rules from visual patterns (Hampshire, Thompson, Duncan, & Owen, 2011; Watson & Chatterjee, 2012) and when comparing the characteristics shared by pairs of people (Cho et al., 2010). In adolescents, a higher level of cortical maturity in prefrontal areas was found to reflect a better performance on a scene analogy task (Krawczyk et al., 2010). In the verbal domain, imaging studies have shown raised left prefrontal cortex activity when evaluating the relationships between semantic relationships (Bunge, Wendelken, Badre, & Wagner, 2005; Green, Fugelsang, Kraemer, Shamosh, & Dunbar, 2006; Green, Kraemer, Fugelsang, Gray, & Dunbar, 2010; Green, Kraemer, Fugelsang, Gray, & Dunbar, 2012). Event-related potentials have been used to find increased prefrontal activity for both a semantic analogical reasoning task (Maguire, McClelland, Donovan, Tillman, & Krawczyk, 2012) and a graphemic analogical reasoning task (Qiu, Li, Chen, & Zhang, 2008). However, despite this evidence, the specific localisation of processes supporting abstraction within the frontal lobes remains debated.

1.2. Proverbs and the frontal lobes

One of the most regularly used frontal lobe tasks tapping abstraction is proverb interpretation (see Gorham, 1956; Delis, Kaplan, & Kramer, 2001). As an aspect of figurative language, proverbs are familiar, fixed, sentential expressions that express well-known truths, social norms or moral concerns (Gibbs & Beitel, 1995). Common examples are *Rome wasn't built in a day* and *All that glitters is not gold*. Proverb tasks assess the ability to interpret the proverbial statement in an abstract or metaphorical rather than a concrete sense, as the proverb's meaning must be generalised to more scenarios than are reflected literally in the proverb itself (Delis et al., 2001, p. 205; Gibbs & Beitel, 1995). Impaired interpretations of proverbs have been regarded as an indicative of dysfunction in higher-level thinking processes linked with the frontal lobes. For example, Zeigarnik (1927), quoted by Luria, 1966 found evidence that patients with frontal lobe damage were unable to connect the literal and the metaphorical meanings of proverbs. Thus, one patient was noted as choosing the literal, rather than the correct abstract interpretation of the proverbs in a multiple-choice trial. Impaired proverb interpretation has been reported in other conditions affecting the frontal lobes such as Parkinson's disease (Levin, Llabre, & Weiner, 1989). An increased tendency to interpret proverbs in a concrete sense in older people was found to be associated with decreased frontal executive skills (Albert, Wolfe, & Lafleche, 1990; Uekermann, Thoma, & Daum, 2008).

Despite their popularity as an assessment tool, relatively few studies have investigated the effects of focal cortical lesions on the ability to interpret proverbs. In an older study, where the basis for the classification of lesion location was not clear, Benton (1968) found that patients with bilateral frontal damage were significantly impaired in interpreting proverbs relative to those with unilateral damage. There was a trend towards a stronger performance in the left frontal group compared to the right frontal group with notable percentages of patients from each group (left frontal: 20%, right frontal: 25%, bilateral: 71%) performing in the impaired range.

In a more recent study, McDonald, Delis, Kramer, Tecoma, and Iragui (2008) compared patients with frontal lobe epilepsy (FLE), temporal lobe epilepsy (TLE) and healthy controls (HC's) on a proverb interpretation task (PIT). To our knowledge, this is the only study where a systematic analysis of the errors made by frontal lobe patients on a PIT was undertaken. On an overall test score, FLE patients differed significantly from HC's, but not from TLE patients in terms of proverb interpretation. In a multiple-choice trial, only FLE patients showed an increased tendency to choose concrete interpretations of the proverb. A further contrast based on the lateralisation of seizures showed that patients with left-sided FLE showed significantly poorer abstraction relative to the right-sided FLE patients.

Roca et al. (2010) reported data on a PIT from frontal lobe patients as part of a wider study of the nature of executive function deficits. The authors found that the frontal group as a whole was significantly impaired on proverb interpretation relative to HC's. In a further group comparison, no difference was found between four different frontal subgroups: superior medial, inferior medial, left lateral and right lateral. Although a significant correlation was found between performance on the PIT and a test of fluid intelligence, patients and controls still differed on the PIT following adjustment for fluid intelligence. This indicates that proverb interpretation could not be entirely explained by a deficit in fluid intelligence. A subsequent lesion analysis examined the performance of six patients who performed the worst on five tests, including the PIT, where fluid intelligence did not account entirely for differences between patients and controls. This indicated that anterior (particularly right) frontal cortex was associated with the remaining deficits on these tests once the variance associated with fluid intelligence was accounted for. The authors suggested that lesions to this area may have damaged a "common processing theme" linking performance on these five tests.

1.3. Figurative language and the frontal lobes

The interpretation of proverbs, which undoubtedly requires the understanding of metaphor (Gibbs & Beitel, 1995), can be viewed as a part of the broader area of figurative language processes. Studies of brain damaged patients have provided evidence for frontal lobe involvement in such processes. Impaired idiom comprehension has been demonstrated following frontal lobe damage (Cacciari et al., 2006; Papagno, Curti, Rizzo, Crippa, & Colombo, 2006). This impairment has been shown to be associated with executive function deficits in Alzheimer's disease (Papagno, Lucchelli, Muggia, & Rizzo, 2003). A reversed-concreteness effect was found for idiom comprehension in a patient with temporal lobe damage and a spared PFC (Papagno & Cacciari, 2010). In this study, interpretation of unambiguous and thus less figurative idioms was selectively impaired, with ambiguous idiom comprehension unimpaired. Impairments in metaphor processing have been associated with decreased activity in the left inferior frontal gyrus in patients with traumatic brain injury (Yang, Fuller, Khodaparast, & Krawczyk, 2010) and patients with schizophrenia (Kircher, Leube, Erb, Grodd, & Rapp, 2007), a condition linked with deficits in frontal executive functions (Minzenberg, Laird, Thelen, Carter, & Glahn, 2009).

In healthy subjects, neuroimaging studies have found associations between idiom comprehension and activity in left superior medial frontal gyrus and left inferior frontal gyrus (Romero Lauro, Tettamanti, Cappa, & Papagno, 2008), bilateral inferior frontal gyri (Zempleni, Haverkort, Renken, & Stowe, 2007), and left ventral dorsolateral PFC (Hillert & Buračas, 2009). One study utilising transcranial magnetic stimulation has indicated that left and right dorsolateral PFC is involved in idiom comprehension (Rizzo, Sandrini, & Papagno, 2007). Reading of metaphors has been associated with left inferior frontal gyrus activity (Rapp, Leube, Erb, Grodd, & Kircher, 2004; Stringaris, Medford, Giampietro, Brammer, & David, 2007).

There is ongoing debate regarding the role of left and right hemispheres in figurative language processing. Influential accounts have accorded a crucial role for right hemisphere regions through suppressing literal interpretations of figurative language or by processing less salient meanings (e.g. Bookheimer, 2002; Giora, Zaidel, Soroker, Batori, & Kasher, 2000; Stringaris et al.,