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Research Report

The impact of egocentric vs. allocentric agency attributions on the neural bases of reasoning about social rules

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ABSTRACT

We used the "standard" and "switched" social contract versions of the Wason Selection-task to investigate the neural bases of human reasoning about social rules. Both these versions typically elicit the deontically correct answer, i.e. the proper identification of the violations of a conditional obligation. Only in the standard version of the task, however, this response corresponds to the logically correct one. We took advantage of this differential adherence to logical vs. deontical accuracy to test the different predictions of logic rule-based vs. visuospatial accounts of inferential abilities in 14 participants who solved the standard and switched versions of the Selection-task during functional-Magnetic-Resonance-Imaging. Both versions activated the well known left fronto-parietal network of deductive reasoning. The standard version additionally recruited the medial parietal and right inferior parietal cortex, previously associated with mental imagery and with the adoption of egocentric vs. allocentric spatial reference frames. These results suggest that visuospatial processes encoding one's own subjective experience in social interactions may support and shape the interpretation of deductive arguments and/or the resulting inferences, thus contributing to elicit content effects in human reasoning.

1. Introduction

The neural bases of deductive reasoning, i.e. the ability to reach secure conclusions from a set of given facts known to be true, have been extensively investigated with functional neuroimaging. Despite complex and not always consistent results (Monti et al., 2007), the role of a common left frontolateral-frontomesial-parietal network across different

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deductive tasks was confirmed by qualitative (Goel, 2007) and quantitative (Prado et al., 2011) meta-analyses. Moreover, against the existence of a single – either rule-based (Rips, 1994) or visuospatial (Johnson-Laird, 1995) – neural system for deductive reasoning, different types of arguments flexibly recruit specific regions, namely right hemispheric visuospatial areas for relational reasoning and left inferior frontal ones for categorical reasoning (Prado et al., 2011). Other regions seem to underpin specific sub-processes, namely extraction and maintenance of the formal structure of arguments (fronto-parietal "support" areas; Rypma et al., 1999; Tanaka et al., 2005), as well as deductive operations (medial and rostrolateral prefrontal "core-logic" areas; Charron and Koechlin, 2010; Christoff et al., 2001; Volz et al., 2005) (Monti et al., 2007, 2009).

Formal logic, i.e. the syntax of classical logic, has been traditionally considered a normative standard for deductive reasoning. Several studies, however, report systematic violations of formal logic in human reasoning, including so-called "content effects" on the Wason Selection task (Wason, 1983). In this task, subjects are asked to identify the violations of a conditional rule ("If P, then Q"), by testing the co-occurrence of its possible antecedents and consequents (P, not-P, Q, not-Q). The correct logical answer is to select P and not-Q, because they could reveal not-Q and P, respectively. However, subjects presented with so-called "descriptive" rules (i.e. describing states of the world, such as "*If a person goes to X, then he does* Y") typically deviate from formal logic (below 20% accuracy, frequently selecting P and Q, or P alone; Manktelow and Evans, 1979). A significant improvement (65–80% accuracy) is observed with "deontic" conditional rules (i.e., describing situations in which, to obtain a benefit P, an individual must satisfy a requirement Q), such as social contracts of the form "*If I give you X, then you must give me* Y" (Manktelow and Over, 1991). The roots of this facilitation have been addressed from both cognitive (Cosmides, 1989; Fodor, 2000; Sperber and Girotto, 2002; Stenning and van Lambalgen, 2004) and social–psychological (Legrenzi, 2004; Pantaleo, 2004) viewpoints. Deontic reasoning competence is sensitive to both context and perspective (Gigerenzer and Hug, 1992), and the facilitation induced by social contracts, as well as by precautionary rules such as "*If the hazard X exists, then you must take the precaution* Y" (Fiddick et al., 2000), may reflect the engagement of domain-specific reasoning mechanisms (Fiddick, 2004). Several studies have highlighted brain regions differentially activated by social contracts vs. descriptive rules (Canessa et al., 2005), social contracts vs. precautionary rules (Fiddick et al., 2005), social contracts or precautionary rules vs. descriptive rules (Ermer et al., 2006), as well as reflecting selective impairments on social contract, relative to precautionary, reasoning (Stone et al., 2002).

The influence of extra-logical considerations on human reasoning is supported by a variant of the task, directly comparing logical vs. deontical accuracy despite an identical structure. In this variant, the "standard" version "*If you take the benefit, then you must satisfy the requirement*" is "switched" into the form "*If you satisfy the requirement, then you (may) take the benefit*" (Cosmides, 1989). In both cases, subjects testing a violation of the rule typically (e.g. 80%; Sugiyama et al., 2002) choose the "benefit accepted" and "requirement non satisfied" cards. However, only in the "standard" version these cards incidentally correspond to the logically correct answer (P and not-Q), while in the "switched" version they correspond to the logically incorrect one (not-P and Q). Here we take advantage of this peculiar feature to test the hypothesis that the predominance of extra-logical considerations in reasoning on social contracts would reflect in neural activity exceeding "core-logic" brain regions. In particular, previous studies highlighted the *perspective* adopted to interpret the rule as a critical factor in social contract reasoning (Fiddick et al., 2000; Gigerenzer and Hug, 1992). Compared with descriptive rules, social contracts may be more easily encoded through visuospatial imagery processes rather than logic deductive operations. Their antecedents and consequents would thus be mapped onto a representational format other than that predicted by formal logic, e.g. in terms of spatial relationships between two interacting agents. This hypothesis would entail a differential involvement of neural mechanisms supporting one's own perspective and sense of agency across the standard and switched tasks, which engage opposite reference frames and corresponding social focal points with respect to the conditional obligation ("If *I*…, then you…" vs. "If *you*…, then I…", respectively). Namely, it would entail an egocentric reference frame – or social focal point – in the standard task, in which the antecedent is encoded in a first-person perspective ("If *I* …"), while the switched task ("If *you* …") can be expected to activate an allocentric reference frame.

We tested this hypothesis in 14 participants who solved the standard and switched versions of the Selection-task during functional-Magnetic-Resonance-Imaging. We predicted that the two tasks would involve differential activity in the regions associated with the adoption of egocentric vs. allocentric reference frames (medial parietal and inferior parietal cortex; Vogeley and Fink, 2003) rather than in the regions involved in logical processing (rostrolateral prefrontal cortex; Monti et al., 2007). We also performed regions-of-interest analyses to assess the consistency of our results with available data on the neural bases of deductive reasoning, reasoning on social contracts, logical inference and agency attribution in social interactions.

2. Results

2.1. *Behavioral results*

We considered as a correct answer in the standard (SSC) and switched (WSC) tasks the selection of both the "benefit accepted" and "requirement non satisfied" cards, regardless of their logical status (e.g. P and not-Q in the SSC task, not-P and Q in the WSC task). Under this convention, behavioral results during functional scanning showed no significant difference between the mean of correct answers in the SSC (mean=81.25%, SD=0.28) and WSC (mean=80.80%, SD=0.29) tasks, $F(2)=2.412$, MSE=0.9, $p>0.05$. Neither a significant main effect of the order of task presentation throughout the four scanning sequences, $F(3)=1.047$, MSE=0.124, $p>0.05$, nor a significant interaction between the task and the presentation order, $F(6)=0.529$, MSE=0.46, $p>0.05$, was observed, indicating that no learning occurred during the experiment.