Selective impairment of reasoning about social exchange in a patient with bilateral limbic system damage

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Social exchange is a pervasive feature of human social life. Models in evolutionary biology predict that for social exchange to evolve in a species, individuals must be able to detect cheaters (nonreciprocators). Previous research suggests that humans have a cognitive mechanism specialized for detecting cheaters. Here we provide neurological evidence indicating that social exchange reasoning can be selectively impaired while reasoning about other domains is left intact. The patient, R.M., had extensive bilateral limbic system damage, affecting orbitofrontal cortex, temporal pole, and amygdala. We compared his performance on two types of reasoning problem that were closely matched in form and equally difficult for control subjects: social contract rules (of the form, "If you take the benefit, then you must satisfy the requirement") and precaution rules (of the form, "If you engage in hazardous activity X, then you must take precaution Y"). R.M. performed significantly worse in social contract reasoning than in precaution reasoning, when compared both with normal controls and with other brain-damaged subjects. This dissociation in reasoning performance provides evidence that reasoning about social exchange is a specialized and separable component of human social intelligence, and is consistent with other research indicating that the brain processes information about the social world differently from other types of information.

Social exchange—cooperation for mutual benefit—is an ancient, pervasive, and cross-culturally universal feature of human social life (1–5), and its presence in related Old World primate species suggests that it may be at least as old as our genus (4, 5). Game-theoretic models predict that for social exchange to persist stably within a species, individuals of that species must be able both to detect cheaters (i.e., individuals who do not reciprocate) and to direct future benefits to reciprocators, not cheaters (6, 7). This prediction prompted the search for cognitive processes with these properties in humans. Here we provide neurological evidence suggesting that social exchange reasoning can be dissociated from reasoning about other domains.

Research on conditional reasoning has provided evidence that the human mind contains processes specialized for detecting cheaters (8–13). Reasoning was a useful avenue for investigating the psychology of social exchange, because social exchange involves a conditional: *If A provides a requested benefit to or meets the requirement of B, then B will provide a rationed benefit to A.* (Herein, a conditional rule expressing this kind of agreement to cooperate will be referred to as a social contract.) A cheater is someone who takes a benefit without meeting the provisioner's requirement.

A principal tool used to investigate conditional reasoning is Wason's four-card selection task (14–16). Subjects are asked to identify possible violations of a conditional rule: "If *P* then *Q*" (see Fig. 1). Rules with abstract or descriptive content—conditionals describing some state of the world—typically elicit a correct response (*P* and *not-Q*) from only 5–30% of subjects tested. This finding is robust: performance in normal subjects remains at these low levels even when the rules tested are familiar, or when subjects are trained, taught logic, or given incentives (8–10, 14–16). In contrast, 65–80% of subjects give correct responses when the conditional rule expresses a social contract, and a violation represents cheating, even on culturally unfamiliar rules (8–11). (See Fig. 1.) This spike in performance when the conditional is a social contract has been found widely in industrialized nations (8–11, 17) and, in the accompanying paper, recently has been observed even among isolated, nonliterate hunter-horticulturalists (18). Cognitive experiments have demonstrated that the activation of this heightened performance is sensitively regulated by the series of variables expected if this were a system whose function were to reason specifically about social exchange, rather than about a broader class of contents (8–13, 18).

These results are congruent with an increasing number of reports from the cognitive neuroscience and cognitive development literature that the processing of social information is distinct from the processing of other kinds of information, and indeed that inputs may be broken down into even more fine-grained sets or domains that are then processed differently according to kind. Domains that have been proposed to be distinct include faces, objects, mental states, biological kinds, and number (19–22). If there is a social contract inference system that is, in some way, functionally distinct from reasoning processes that operate in other domains, then performance in reasoning about social contracts could become impaired without necessarily affecting reasoning performance in other domains. (Regardless of the ontogenetic or phylogenetic origins of this system, dissociation is a test of its independence in adults.)

The search for a selective deficit in social contract reasoning is made easier by the existence of a nearly identical reasoning task that can be used as a control, in which normal subjects also perform well. Sixty-five to 80% of subjects give correct responses on the Wason selection task when the conditional (If *P*, then *Q*) has the form of a precaution rule: "If you engage in hazardous activity X, then you must take precaution Y" (12, 13, 22–25, **). (See Fig. 1.) Judging precaution violations and detecting cheaters on a social contract are so alike that, according to alternative theories, the cognitive architecture of the human mind does not distinguish between them. Like social contracts, precaution rules are conditional, deontic (they express the conditions under which a person is permitted to take action X, or is obliged to take precaution Y), and involve utilities.

While some propose that there is a separate cognitive specialization for reasoning about hazards parallel to a social

PSYCHOLOGY

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**Manktelow, K. & Over, D., First International Conference on Thinking, 1988, Plymouth, U.K.

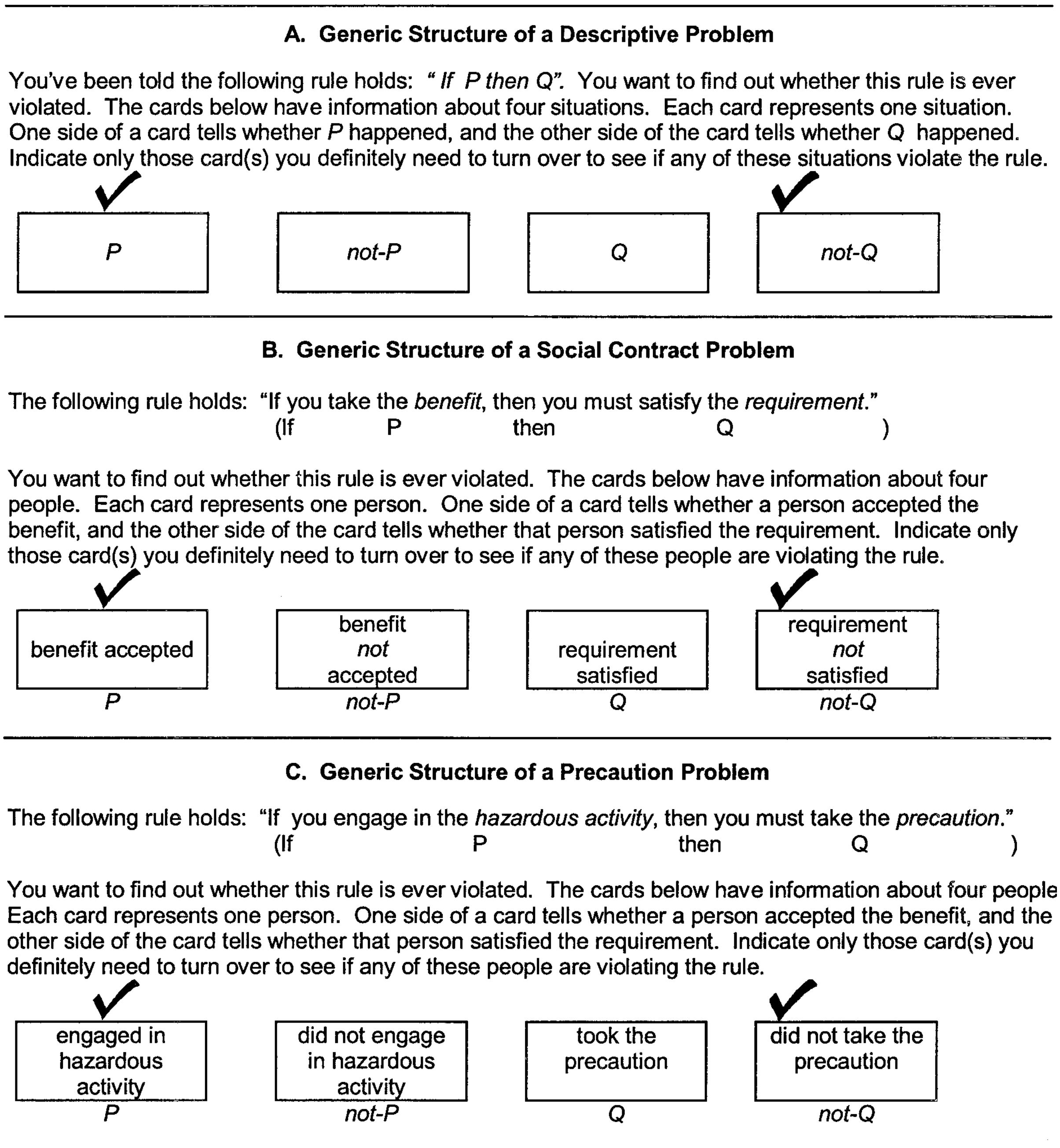

Fig. 1. The Wason selection task: Generic structures of descriptive (*A*), social contract (*B*), and precaution (*C*) problems. All have the same logical structure, "If *P* then *Q*." They differ only in content (i.e., what *P* and *Q* stand for): social contracts specify benefits that are contingent on meeting the provisioner's requirement (e.g., "If you borrow my car, then you have to fill up the tank with gas"), whereas precaution rules specify hazardous activities that can be made safer by taking an appropriate precaution (e.g., "If you do a trapeze act, you must use a safety net"). Check marks indicate correct card choices. (*P*s, *Q*s, and check marks do not appear on forms seen by subjects.)

contract specialization (12, 13), most theories of reasoning propose that cheater detection and precautionary reasoning are both accomplished by more general-purpose mechanisms that are designed to operate on a single, more inclusive, class of content: either any conditional rule (26–28), any rule with certain pragmatic implications (29), any deontic rule—i.e., any rule expressing permission, obligation, or entitlement (17, 25, 30), or any deontic rule involving utilities (26).

If, as these theories propose, a single set of reasoning procedures operates over both types of rules, then brain damage that degrades performance on one type of rule should degrade it on the other, because there is only one cognitive mechanism to be damaged. If, in contrast, there are two reasoning specializations, one for social exchange and another for managing hazards, then it is possible for one system to be damaged whereas the other is spared. Although cognitive experiments on normal subjects are consistent with two mechanisms (12, 13), the data reported here are different because they involve a neurological dissociation.

Methods

Neurological Case. The patient, R.M., suffered a bicycle accident in 1974, when he was 25, causing bilateral damage to medial

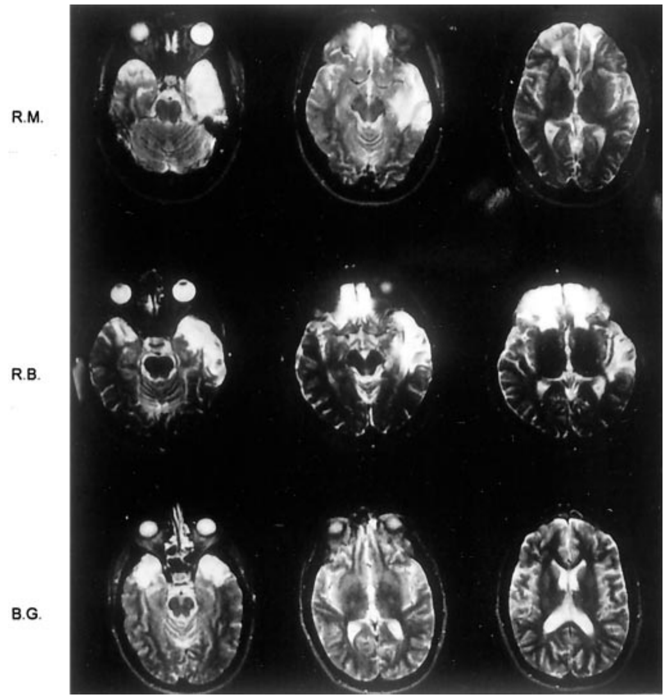

Fig. 2. Structural MRI scans showing R.M.'s damage compared with that of patients R.B. and B.G. T2 weighted axial MRI scans show the extent of damage. R.M.'s damage includes areas 10, and parts of 11 and 12. In addition, he has severe left damage in the anterior lateral and basal structures of the temporal lobe. The left amygdala is spared but input from perirhinal cortex and the anterior temporal pole is lost. The right anterior temporal pole is also severely damaged. The temporal pole is the main source of input into the amygdala (33); thus, lacking critical temporal pole input, both amygdaloid complexes are disconnected. R.B. has bilateral orbitofrontal and anterior temporal damage without amygdala disconnection. B.G. has bilateral anterior temporal but no orbitofrontal damage. R.B. has the greatest volume of tissue damage.

orbitofrontal cortex and anterior temporal cortex. The anterior temporal damage on both sides was extensive enough to disconnect both the right and left amygdala (31–33). (See Fig. 2 and *Appendix*.) These areas of the brain are key areas for social intelligence. R.M. was a particularly interesting case in which to test our hypothesis, because previous studies indicated that he had pronounced difficulty with social intelligence, i.e., making inferences about others' thoughts and feelings and recognizing mental state terms, such as *know, think,* and *imagine* (21, 22, 32, ††). (See Table 1.)

R.M. suffered severe retrograde amnesia after his accident. Details of his episodic memory impairment have been reported elsewhere (31). His Wechsler Adult Intelligence Scale verbal IQ is 92 and performance IQ is 102. He performed normally on the Category Test (similar to the Wisconsin, but more demanding in the level of abstraction required), the Tower of Hanoi, and verbal fluency (F-A-S test), and was only mildly impaired on the Wisconsin Card Sorting Test, because of perseverative errors. R.M. performed normally on the Trail Making Test and the Rey–Ostierreth Figure. This set of results indicates executive and visuospatial function within the normal range, with some mild perseveration. He can easily perform simple calculations and remember the locations of objects that he saw being hidden 2 weeks before. He volunteered 5 days a week at a local hospital, was socially interactive, even though he sometimes found social interactions puzzling, and was well known and liked by his coworkers.

Table 1. Patients' performance on tasks measuring understanding of other people's mental states

	% agreement with norm subjects' scores		
Task	Patient R.M.	Patient R.B.	Patient B.G.
Recognition of faux pas	80	100	100
Recognition of mental state terms	82	97	96
Recognition of body terms	100	96	94

The faux pas recognition task gives subjects brief stories and measures whether subjects understand that someone has said something awkward or insulting unintentionally (32, 45, 46, ††). The recognition of mental state terms task gives subjects a list of terms such as *know*, *think*, *remember*, *tape*, *park*, and *county*, and asks them to say for each one whether it has to do with the mind. As a control task, they are given a list of terms that may or may not have to do with the body and asked for each one to say whether it has to do with the body. R.B. and B.G. are comparison patients with damage similar to, but not co-extensive with, that of R.M.

Social Contract Reasoning Stimuli. We developed a set of 65 reasoning problems using the Wason selection task, and normed each on 37 normal non-brain-damaged control subjects (see *Appendix* for details). The set was composed of social contracts, precautions, and descriptive rules (included to establish a baseline). Consistent with other studies in the literature, control subjects performed well (>65% correct) on the social contract problems and on the precaution problems (see Table 2), and relatively poorly on the descriptive problems (<35% correct).

Great care was taken to use a set of social contract reasoning problems and precaution reasoning problems that were logically equivalent, matched for task demands, and well matched for difficulty (see *Appendix*). The performance of the normal controls demonstrates that these efforts were successful. As a group, there was no difference in their performance on the social contracts and precautions (see Table 2; see *Appendix* for statistical details). More importantly, social contracts and precautions elicited equivalent performance even when one compares performance *within* individuals. Difference scores between precaution and social exchange, calculated for each subject as percent correct for precaution problems minus percent correct for social contract problems, were normally distributed around a mean of 1.2 percentage points (SD = 11.5).

Results

R.M. made errors on significantly more of the social contract problems than the precaution problems ($z = 1.96, p < 0.02, \phi = 0.31$; see Fig. 3). The difference between his score on the precaution reasoning problems and on the social contract problems was 31 percentage points (70% − 38.9%), significantly different from the 1.2 percentage point mean difference score of control subjects ($z = 2.61, p < 0.005, \phi = 0.30$). We also analyzed the particular types of errors that he made, and found no significant differences from control subjects.

R.M.'s performance on the reasoning problems with abstract/descriptive rules (16.7% correct) was comparable to that of controls ($z = 0.55$, $p = 0.21$, $\phi = 0.09$).

To rule out the possibility that R.M.'s impairment could be attributed simply to his having extensive bilateral damage, we also tested two other patients, B.G. and R.B., with extensive bilateral lesions in areas that overlapped with the areas of R.M.'s damage (orbitofrontal cortex and temporal poles), although the exact extent and patterns of damage were different (31, 32). B.G. had extensive bilateral temporal pole damage compromising

††Stone, V. & Baron-Cohen, S., Cognitive Neuroscience Society, March 1994, San Francisco.

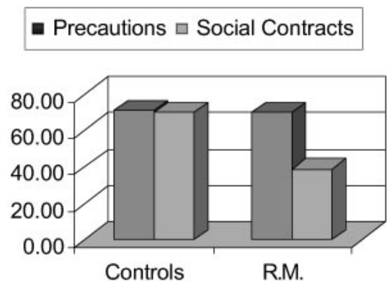

Fig. 3. Performance of control subjects and R.M. on social contract and precaution reasoning problems. Control subjects did equally well on social contract and precaution problems. R.M. did not: his performance on social contracts was impaired relative to his performance on precautions.

input into both amygdala, but his orbitofrontal cortex was completely spared. R.B. had more extensive bilateral orbitofrontal damage than R.M., but his right temporal pole was largely spared, and thus he did not have bilateral disconnection of the amygdala. Neither B.G. nor R.B. performed significantly differently on the two sets of problems: R.B. scored 83% correct for the social contract problems and 85% correct for the precaution problems and B.G. scored 100% correct on both types of problem (Table 2). Thus, the selective deficit in social contract reasoning appears to be an effect not of lesion size *per se*, but of bilateral damage compromising both components of the limbic system: orbitofrontal cortex and amygdala.

Discussion

Alternative Hypotheses. In patients demonstrating a single dissociation, such as R.M., the objection can always be raised that one set of stimuli is, for incidental reasons, simply more difficult than the other and therefore taxes the cognitive capacity of a patient with brain damage more than the other set. This is unlikely to be true in R.M.'s case, for three reasons. First, we controlled for incidental sources of difficulty by choosing logically equivalent reasoning problems, closely matched for task demands and word length, and closely matched for the performance norms of normal subjects. Given that the performance of normal controls on precautions and social contracts was statistically identical—yet not at ceiling, eliminating the possibility that a ceiling effect was masking real differences in difficulty—we conclude that the two sets of problems were equally difficult and would have been equally taxing to R.M (see *Appendix*). Second, two patients with large bilateral lesions performed at the same level on the two types of problems. (In fact, R.B. had the greatest volume of tissue damage, yet showed no impairment.)

Third, the individual problems that were the most difficult for control subjects were not necessarily the problems on which R.M. made errors. The performance of normal subjects is the only nonarbitrary measure of a problem's difficulty: difficult problems can be operationally defined as those that elicit the most errors. We calculated the proportion of normal controls who got each problem correct and correlated these scores with whether R.M. got that problem correct. These correlations were near zero, and in the wrong direction (for the set of 18 social contract problems, $r = -0.19$; for the set of 23 precaution problems, $r = -0.057$). Knowing which individual problems control subjects found most difficult does not allow one to predict R.M.'s errors.

R.M.'s errors cannot be attributed to how difficult individual problems were, or to the relative difficulty of the two problem sets. Instead, his differential deficit appears to reflect the content of the problems. R.M.'s ability to detect cheaters on social contracts is impaired relative to his ability to detect violations of logically and deontically equivalent precaution rules. This deficit is consistent with his daily life experience. He has difficulty making his own financial decisions, and his family has said that he does not realize if someone is taking advantage of him.

The findings reported with this single patient would be significantly strengthened by demonstration of a double dissociation, finding the reverse pattern of results in another patient. Although rare compared with patients with orbitofrontal damage, patients with damage restricted to medial frontal cortex or anterior cingulate might be a possible group in which to look for such a pattern. Anterior cingulate and medial frontal cortex are activated in situations in which subjects experience anticipatory anxiety or anticipate pain occurring (34, 35). Patients with damage to medial frontal cortex may not experience normal levels of anxiety in appropriate situations (36). Obsessive-compulsive disorder (OCD) could be seen as a hyperactivated precaution system (37), and OCD does involve abnormally high levels of activity in the anterior cingulate, thought to result in excessive error-monitoring or affective responses to anticipated errors (38, 39). Thus, it is possible that patients with lesions specifically affecting anticipatory anxiety might show the reverse pattern of results to those reported here. We would welcome such an investigation.

The Social Brain. Single cases are most useful for demonstrating dissociations, not for making strong claims about the function of the underlying lesion areas. However, these results are consistent with other recent reports of social information processing deficits in patients with damage to orbitofrontal cortex or the amygdala (32, 40–46). Patients with bilateral amygdala damage, in particular, have been shown to have difficulty doing a task that is arguably related to cheater detection: judging trustworthiness from the face (40). Whereas orbitofrontal or amygdala damage by itself is enough to produce deficits in the ability to infer others' thoughts and feelings (32, 45), damage to each region individually is not sufficient to impair cheater detection.

The main difference between R.M. and the other patients we tested is that he is the only one with complete bilateral damage affecting both orbitofrontal cortex and the amygdala. There may be enough redundancy for certain social abilities that only complete bilateral damage to both components of the limbic system could lead to a deficit in cheater detection. In contrast, it is clear that even complete bilateral damage to these areas does not impair reasoning about precautions.

Patients with damage to orbitofrontal cortex, the amygdala, or both, are often vulnerable to scams, bad business deals, and exploitative relationships, a vulnerability that may be affected by deficits in specific aspects of social cognition (45, 47). By better understanding the specific social deficits suffered by these types of patients, we can begin to discover the component processes of social intelligence, and how they are related to underlying brain regions.

Conclusions

Knowing how to engage in social exchange is an important aspect of human social intelligence. R.M.'s differential impairment

Table 2. Performance on reasoning problems by patients and normal controls

	% correct			
	Patient R.M.	Patient R.B.	Patient B.G.	Controls (mean)
Precaution rules	70.0	85.0	100	71.0
Social contracts	38.9	83.0	100	69.8
Difference score	31.1	2.0	0	1.2

indicates that being able to detect potential cheaters may be a separable component of the human mind. These findings, showing that one kind of reasoning can be dissociated from another by content, are at variance with those theories that consider human reasoning to be carried out by more general procedures, and that therefore do not consider reasoning about social exchange to be a distinct process. This dissociation in reasoning performance on rules that are similar along so many different dimensions is surprising, except on the theory that humans' cognitive architecture reliably develops functionally distinct procedures designed for reasoning about social exchange and detecting cheaters. Together with other research, it suggests that human social intelligence may consist of a number of functionally specialized components.

Appendix

Task. The Wason selection task (see Fig. 1) is a useful assay for content-dependent reasoning systems. Social contract and precaution rules elicit spikes in performance; in contrast, performance is low for conditional rules that do not involve social exchange or precautions, whether that rule describes a state of the world, or prescribes how it should be (the "descriptive" rules in this study fell into both categories) (8–13).

Reasoning Stimuli. We developed a set of reasoning problems using the Wason selection task. There were three types of problems: social contracts (e.g., "If you go canoeing on the lake, then you have to have a clean bunk house"), precaution rules (e.g., "If you work with toxic chemicals, then you have to wear a safety mask"), and descriptive rules (e.g., "If a person has arthritis, then that person must be over 40 years old"). For other examples, see Fig. 1. The full set of problems used is posted on www.du.edu/~vstone/wason.htm.

A large set of problems was normed on non-brain-damaged control subjects (37 subjects answered each problem). To be conservative, we selected for analysis only those social contract and precaution problems that 65% or more of the control subjects got correct, as an indication that these were successful exemplars of this problem type. (If we had included the entire set of problems, R.M.'s selective impairment would have appeared more extreme.) This selection resulted in a stimulus set that included 18 social contract rules, 23 precaution rules, and 24 descriptive rules.

The social contract and precaution reasoning problems were logically equivalent, matched for task demands, and well matched for difficulty. All of the social contracts and precautions were permission rules [as defined by pragmatic reasoning theory (17, 25)] and therefore logically (and deontically) equivalent. The average length of the social contract problems was 153.7 words, and that of the precaution problems was 154.0 words; thus they were well matched for verbal complexity and memory load. Moreover, they elicited equivalent performance from non-brain-damaged subjects. Consistent with other studies in the literature, control subjects performed well on the social contract problems (69.8% correct, SD = 36.5) and on the precaution problems (71.0%, SD = 35.4), and relatively poorly on the abstract/descriptive problems (34.3%, SD = 31.8). (See Table 2.)

As is typical, the control data were bimodally distributed, with over 70% of subjects performing at 65% correct or better, a scattering of subjects in the middle of the range, and a minority (≈15%) performing between 0 and 20% correct (hence the standard deviation scores). This last group performed poorly across all three problems; this does not reflect incapacity, but rather inattention to the content of the rules (11). (Excluding these subjects from the norming group would not have changed the average difference scores significantly; see below.)

Difficulty of social contract and precaution problems was matched, whether one looks at group data or individual data for the control subjects. Difference scores between precaution and social exchange, calculated for each subject as percent correct for precaution problems minus percent correct for social contract problems, were normally distributed around a mean of 1.2 percentage points (SD = 11.5).

Anatomical and Neuropsychological Profiles. The anatomical profiles of R.M., R.B., and B.G. have been reported in extensive detail elsewhere; see refs. 31 and 32. Details of R.M.'s and R.B.'s memory impairment and performance on neuropsychological tests can be found in ref. 31.

PSYCHOLOGY

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