

Reflective and Reflexive Action Control in Patients With Frontal Brain Lesions

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Two types of action control derived from the model of action phases (H. Heckhausen & P. M. Gollwitzer, 1987) were analyzed in patients with frontal lesions, patients with nonfrontal lesions, and university students. In Study 1, reflective action control in terms of goal selection was assessed, and impaired deliberation was found in patients with frontal lesions. Study 2 assessed reflexive action control in terms of automatic action initiation as a result of forming implementation intentions (P. M. Gollwitzer, 1999). All participants sped up their responses to critical stimuli by forming implementation intentions. Moreover, lesion patients with weak performances on the Tower of Hanoi (TOH) task did worse than patients with strong TOH performances in Study 1 but better than control participants in Study 2. Findings are interpreted as a functional dissociation between conscious reflective action control and automatic reflexive action control.

Patients with frontal lobe damage are often unable to cope with everyday life despite their unaffected performance in tests of intelligence, language, memory, and perception (Grattan & Eslinger, 1991). This discrepancy has stimulated various models describing the planning and action control deficits in patients with frontal brain lesions.

For a long time, the frontal lobes have been considered to be involved in regulating and programming behavior (e.g., Harlow, 1896/1993; Luria, 1962, 1973; Pribram, 1987; Pribram & Tubbs, 1967). Hierarchical models of brain functioning (Stuss & Benson, 1986; Tranel, Anderson, & Benton, 1994) assume that executive functions (including anticipation, goal selection, planning, monitoring, and use of feedback), located in the prefrontal cortex, control the lower level fixed functional systems (e.g., attention, memory). Other models make a distinction between explicit and im-

plicit control of action. Processes of the frontal lobes are assumed to be involved whenever a new activity is being learned. However, when an activity has become routine, other brain regions—especially subcortical ones—are said to determine action. For instance, Norman and Shallice (1986) suggested that two processes operate in the selection and control of action: contention scheduling (CS) and the supervisory attentional system (SAS). CS acts through lateral activation and inhibition of action schemas depending on their activation value, and, thus, behavior is triggered automatically. The SAS, in contrast, provides the conscious attentional control of action selection by modulating the activation and inhibition values of action schemas, and thus is assumed to be responsible for planning, decision making, and monitoring behavior. Whereas the SAS is thought to be located in the frontal lobes, CS is assumed to take place in other regions of the brain (possibly the basal ganglia). To support their model, Norman and Shallice (1986) referred to slips of action (Reason, 1987) that occur when action is triggered by CS unmonitored by the SAS.

Indeed, in patients with frontal lesions, heightened frequencies of action slips have been documented in research on utilization behavior (Fukui, Hasegawa, Sugita, & Tsukagoshi, 1993; Lhermitte, 1983; Shallice, Burgess, Schon, & Baxter, 1989), imitation behavior (Lhermitte, Pillon, & Serdaru, 1986; Luria, 1973), environmental dependency (Lhermitte, 1986), novelty preference (D. S. Levine, Leven, & Prueitt, 1992), and capture errors in sequencing (Della Malva, Stuss, D'Alton, & Willmer, 1993). In other words, the intentional goal-directed behaviors of patients with frontal brain lesions are easily disrupted and replaced by routinized and habitual behaviors when the current situation entails the respective triggering stimuli.

Even though defective planning and action control after frontal lobe lesions are well documented in the neuropsychological literature (case studies: e.g., Cockburn, 1995; von Cramon & Matthes-von Cramon, 1994; Damasio, 1985; Konow & Pribram, 1970; overviews: e.g., Fuster, 1989;

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Shallice, 1988; Stuss & Benson, 1986), the concepts of action control and planning are used inconsistently and are only vaguely defined. The neuropsychological assessment of planning also suffers from conceptual vagueness. For example, Tower puzzles are commonly used to assess frontal functions, even though these tasks do not always successfully identify patients with frontal lobe dysfunctions (Levin, Goldstein, Williams, & Eisenberg, 1991; Shallice & Burgess, 1991). Still, there is evidence of impaired performance on Tower puzzles after frontal lobe lesions (e.g., Owen, Downes, Sahakian, Polkey, & Robbins, 1990). In positron emission tomography (PET) and single photon emission computed tomography (SPECT) studies with normal participants, dorsolateral frontal involvement was found during Tower of London performance (Morris, Ahmed, Syed, & Toone, 1993; Rezai et al., 1993).

Accordingly, Tower puzzles seem to assess frontal functions, but it is not clear which functions are assessed. For diagnostic purposes, Tower puzzles are often used to assess the ability to look ahead in planning (e.g., Morris et al., 1993), but they are also used to assess procedural learning (Saint-Cyr, Taylor, & Lang, 1988), which leads to basal ganglia activation in addition to activation in frontal areas (Owen, Doyon, Dagher, Sadikot, & Evans, 1998). Goel and Grafman (1995) recently analyzed the task demands of Tower of Hanoi type problems and argued that it is neither planning nor sequencing that is assessed in these problems but rather the ability to solve goal-subgoal conflicts. Finally, findings from cognitive psychology suggest that Tower puzzles indeed measure different cognitive processes that relate to various stages of strategy acquisition: conscious deliberation (participants use reasoned strategies when first confronted with the task), sequencing, and procedural learning (Simon, 1975; Kotovsky, Hayes, & Simon, 1985).

Jeannerod (1997) recently suggested that planning is "a broad process which can be analyzed and decomposed into more elementary operations" (p. 133). We share this view and maintain that it is important to explicate the concept of planning because it is likely that not all aspects of planning are affected to the same degree by frontal brain lesions. In the present article, we put this hypothesis to the test by exploiting recent advances in action control theorizing. In their model of action phases, Heckhausen and Gollwitzer (1987; Gollwitzer, 1990; Heckhausen, 1991) suggested that intentional control of action necessitates the successful solving of four different tasks. First, people need to set preferences between their wishes and desires by engaging in intensive deliberation of the feasibility and desirability of the potential goals and then turn the most preferred desires into binding goals. Second, once such goal decisions have been made, the next task is to make plans for when, where, and how one intends to implement the chosen goal and to initiate the implementation of goal-directed actions. Third, ongoing goal-directed actions need to be monitored and brought to a successful ending. Fourth, to be able to decide on further goal striving, one needs to evaluate whether the attained outcomes match the originally desired outcomes.

Gollwitzer (1993, 1999) expanded the theorizing on the second task of the action phases model (i.e., planning the initiation of goal-directed actions) by suggesting a distinction between so-called goal intentions ("I intend to achieve x !") and implementation intentions ("And if I encounter the situation y , I will perform the goal-directed behavior z !"). Goal intentions turn desires into binding goals, whereas implementation intentions plan how the goal is going to be attained. Implementation intentions are thus formed in the service of goal intentions and belong to the planning phase of goal attainment. It is assumed that implementation intentions delegate the control of one's actions to the specified anticipated future situations, which, once encountered, initiate the intended goal-directed behaviors automatically. Research has demonstrated that behavior specified in implementation intentions is initiated immediately, efficiently, and without conscious intent (Gollwitzer, 1993, 1999; Gollwitzer & Brandstätter, 1997; Gollwitzer & Schaal, 1998), all of which are characteristic features of automatic action control (Bargh, 1997).

The selection of new goals (i.e., the formation of new goal intentions) would certainly demand conscious reflection, however. Assuming that frontal lobe injuries impair conscious action control processes, patients with a frontal lobe lesion should evidence less deliberation when making goal decisions compared with people without a frontal lobe injury. In Study 1, we tested this hypothesis by confronting patients with frontal lobe lesions, patients with nonfrontal lobe lesions, and university students with numerous different behavioral choice situations that demanded a goal decision.

In contrast, because automatic control of habitualized behavior remains intact after frontal lobe damage, patients with frontal lobe lesions should benefit as much from having formed implementation intentions as control participants. Even though the formation of implementation intentions involves conscious reflection, the initiation of the goal-directed behaviors specified in implementation intentions may solely rely on automatic process. In Study 2, we therefore helped patients with frontal brain lesions, patients with nonfrontal brain lesions, and university students to form implementation intentions and then observed whether the intended goal-directed behavior became automatically controlled to the same degree in all groups.

In both studies, we analyzed complex processes of action control in heterogeneous samples. Therefore, we used repeated measures designs (i.e., within designs) because they most effectively control for relevant premorbid interindividual differences (e.g., education, life experiences, cognitive abilities, sex, age, handedness) and interindividual neurological and neuropsychological differences (e.g., lesion location, deficiencies in cognitive processing, effects of rehabilitation). Accordingly, both studies use mixed between-within factorial experimental designs that allow for comparisons of individual patterns of behavior between patients with frontal brain lesions, other brain-injured patients, and noninjured college students. Within these groups, we compared performances on different types of tasks (i.e.,

decision problems of various difficulty in Study 1 and different types of preparing a critical response in Study 2).

Study 1: Reflective Action Control

Defective decision making is considered to be a typical frontal lobe dysfunction. Problems in decision making have been documented in case studies (e.g., Damasio, Tranel, & Damasio, 1991; Eslinger & Damasio, 1985; Saver & Damasio, 1991), whereas experimental studies directly addressing decision making are rare (Bechara, Damasio, Damasio, & Anderson, 1994; Coolidge & Griego, 1995; Decary & Richer, 1995). Still, experimental studies on problem solving imply that deliberation is hampered in patients with frontal lobe lesions. Moreover, deficiencies in tasks of subject-ordered pointing and recency discrimination not only may indicate defective temporal organization (McAndrews & Milner, 1991; Milner, Petrides, & Smith, 1985; Petrides & Milner, 1982) but also may hint at impaired conscious deliberation (Wiegersma, van der Scheer, & Hijman, 1990). Finally, an inferior performance in the Tower of Hanoi can be interpreted as a deficiency in making goal-subgoal decisions (Goel & Grafman, 1995).

The present experiment directly addresses the issue of deliberating a decision. Participants were confronted with behavioral choice situations that varied in terms of the number and complexity of aspects that needed to be taken into account to arrive at a reasoned decision. The ability to deliberate adequately was thought to be reflected in a close link between the perceived difficulty of the problem and the time spent deliberating on the problem. If this ability is lacking, no positive relation between the perceived difficulty of the problem and the time spent deliberating should prevail. Moreover, the classic result that intensive deliberation increases uncertainty (Mann & Taylor, 1970) should fail to emerge.

We ran four groups of participants: patients with frontal lobe lesions, patients with nonfrontal lobe lesions, and two control groups consisting of university students. In participants with intact frontal lobe functioning, the deliberation time was expected to correlate positively with the perceived difficulty of the presented choice problems and negatively with the rated certainty of the decisions made, whereas no systematic relations were predicted for patients with frontal lobe lesions.

Method

Participants

The clinical sample consisted of 30 brain-injured patients of the Krankenhaus Bogenhausen, München, Germany. Eighteen patients had a frontal brain lesion (7 women, 11 men) and 12 had a nonfrontal brain lesion (2 women, 10 men). In the frontal lobe (FL) group, the mean age was 32.50 years ($SD = 12.00$), and in the nonfrontal lobe (NFL) group, the mean age was 42.92 years ($SD = 13.93$). As nonclinical controls for the frontal lobe (CFL) group, 7 female and 11 male university students were randomly selected from the participant pool of the Max-Planck-Institute for Psychological Research in Munich, Germany; the same procedure

was applied to create a control group for the nonfrontal lobe (CNFL) group as well. The mean age of the two control groups was 25.33 years ($SD = 2.97$) and 24.67 years ($SD = 1.83$), respectively.

Patients' lesions (see Appendix A for single case information) in the FL group were due to head injury ($n = 11$) and cerebrovascular disease ($n = 7$). In the NFL group, head injury ($n = 4$), cerebrovascular disease ($n = 6$), and hypoxia ($n = 2$) were considered to be responsible for the brain lesions. Clinical data about lesion location, etiology, handedness, symptoms of paralysis, and measures of cognitive and motor functions were available in the hospital's files. Patients were selected on the criteria that they would have no reading difficulties (e.g., alexia, aphasia, or fixation problems), would possess an intact understanding of instruction, and would be able to use a pencil with one hand. All patients had more than 40 days of recovery. Twenty-five participants had experienced more than 6 months of recovery and thus qualified as chronic patients (Karnath, Wallesch, & Zimmermann, 1991).

Procedure and Materials

As depressive states are known to increase decision times (Pietromonaco & Rook, 1987), we asked participants at the outset of the experiment to fill out two reliable depression scales: the Beck Depression Inventory (BDI; Beck, Rush, Shaw, & Emery, 1986; Beck & Steer, 1987) and the Center for Epidemiological Studies Depression scale (CES-D; Radloff, 1977). Participants then received a booklet that contained 20 decision problems of equal length (15 lines of text each) concerning various aspects of life (including professional and social issues, shopping, eating, financial investments, transportation or moving; see Appendix B for examples). In constructing the decision problems, we took steps to avoid issues that are gender biased or too far removed from the patients' everyday life. To produce enough variance in perceived difficulty of the decision problems, we constructed problems at different levels of complexity. This was achieved by varying the number of aspects requiring deliberation (e.g., uncertainty of consequences, questionable attractiveness of these consequences, or questionable reversibility of these consequences).

Each problem was embedded in a short story (of equal length) and presented on a different page. Participants were instructed to read each problem and to imagine that they were experiencing it in person. They were told to think about the decision alternatives presented after having read the text and to take as much time as necessary to make a decision. For each decision problem, two decision alternatives were listed, and participants were asked to pick their choice. Immediately after each decision, participants had to answer questions that assessed the perceived difficulty of the decision problem at hand as well as the certainty of having made the correct decision using 10-point rating scales (0 = *not at all difficult*, 9 = *very difficult*; and 0 = *not at all certain*, 9 = *very certain*, respectively). The decision time for each problem was defined as the time from turning the page to marking the chosen alternative. Participants did not know that their decision times were recorded while they worked on the decision problems.

Design

A mixed-factorial design was used, with group (FL, NFL, CFL, CNFL) as the between factor and decision problem (Problems 1–20) as the within factor.

Results

Equivalence of Groups

Before analyzing the individual patterns of behavior (using individual correlation coefficients), we compared group means to explore the differences between groups.

Depression. To assure a valid assessment of depression, we computed a correlation coefficient for the two scales ($r = .65$). The four groups (FL, NFL, CFL, and CNFL) did not differ in terms of their depression levels as assessed by the two scales, $F_{BDI}(3, 56) = 1.68, ns$; $F_{CES-D}(3, 56) = 1.22, ns$. BDI scores in the patient group ($M_{FL} = 12.50, SD = 11.72$; $M_{NFL} = 11.92, SD = 9.58$) were slightly above normal (normal scores are ≤ 11 ; Beck & Steer, 1987), which may be a reaction to the lesion or the experienced abrupt life changes. However, these scores are far below clinical relevance (clinically relevant scores are ≥ 18 ; Beck & Steer, 1987).

Problem difficulty and certainty of decision. To assess the validity of our measures of problem difficulty and certainty of decision, we correlated the perceived difficulty with the rated certainty. The classic finding of a negative relation between certainty and task difficulty (in the sense that easier decisions lead to higher certainty ratings; e.g., Peterson & Pitz, 1988) was confirmed in all groups ($r_{FL} = -.73$; $r_{NFL} = -.71$; $r_{CFL} = -.81$; $r_{CNFL} = -.46$).

We used the students' ratings of the difficulty of the decision problems to classify the 20 problems into three difficulty groups: low, medium, and high. The reliability of this grouping was checked by computing Cronbach's alpha coefficients of internal consistency. The reliability of the scores of perceived difficulty (FL $Mdn = .66$; NFL $Mdn = .74$; CFL $Mdn = .51$; CNFL $Mdn = .72$) and rated certainty (FL $Mdn = .74$; NFL $Mdn = .72$; CFL $Mdn = .52$; CNFL $Mdn = .55$) turned out to be satisfactory. When we computed a 4 (groups: FL, NFL, CFL, CNFL) \times 3 (level of difficulty: low, medium, high) analysis of variance (ANOVA) on the mean perceived difficulty of the decision problems, a highly significant main effect of level of perceived difficulty was observed, $F_{linear\ trend}(1, 56) = 108.00, p < .001, \eta^2 = .66$, which was not qualified by an interaction with group of participants, $F_{linear\ trend}(3, 56) = 1.22, ns$.

This pattern of data suggests that the lesion patients perceived the increase in difficulty of the 20 decision problems just as clearly as the university students did. An analogous analysis conducted on the dependent variable of rated certainty yielded very similar results: effect of problem difficulty, $F_{linear\ trend}(1, 56) = 55.90, p < .001, \eta^2 = .50$; interaction with the group factor, $F_{linear\ trend}(3, 56) = 1.08, ns$.

Decision times. We also computed a 4 (groups: FL, NFL, CFL, CNFL) \times 3 (level of difficulty: low, medium, high) ANOVA on decision times. It yielded a highly significant main effect for the level of difficulty, $F_{linear\ trend}(1, 56) = 4.79, p < .05$, accounting for only 8% of variance ($\eta^2 = .08$), which was not qualified by an interaction effect with the group factor, $F_{linear\ trend}(3, 56) = 1.55, ns$. This time, however, there was a significant main effect of group, $F(3, 56) = 5.71, p < .01$. To understand the nature of the group differences, we compared the clinical groups with their respective student control groups. Whereas both groups of lesion patients responded more slowly than the respective control groups (all $t_s > 2.70, p_s < .01$), no difference was found between the two lesion groups, $t(28) < 0.35, ns$. This pattern of data suggests that all lesion patients needed more time to make decisions than university students, which may be due not only to differences in age but also to a general slowing of information processing in some patients. In the central analyses (see below), we therefore focused on the relation between dependent variables within each individual participant. These individual patterns of data stay unaffected from potential biases rooted in interindividual differences in speed of processing, age, sex, IQ, and so forth.

Amount of Deliberation

The relation between perceived difficulty and decision time. In a first step, over all 20 decision problems a Pearson correlation coefficient between a person's perceived difficulty ratings and that person's decision times was computed for each individual participant. We then standardized these correlation coefficients by transforming them into Fisher's Zs. When computing a mean Z for each

Table 1
Mean Correlation Between Decision Time and Perceived Problem Difficulty as Well as Rated Certainty of Decision for the Different Experimental Groups

Correlation	FL		NFL		CFL		CNFL	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Decision time and perceived problem difficulty	.12 _a	.25	.18 _{a,c}	.39	.38 _b	.30	.35 _{b,c}	.34
Decision time and rated certainty	-.08 _a	.30	-.24 _b	.33	-.26 _c	.27	-.23 _{b,c}	.25

Note. The numbers represent Fisher's Zs. Means in the same row that do not share a common subscript differ at $p < .05$ in planned single contrasts (t tests comparing FL vs. NFL, FL vs. CFL, NFL vs. CNFL, CFL vs. CNFL). FL = patients with frontal lobe lesion; NFL = patients with nonfrontal lobe lesion; CFL = student control group for FL; CNFL = student control group for NFL.

Table 2
Mean Correlation Between Decision Time and Perceived Problem Difficulty as Well as Rated Certainty of Decision as a Function of Performance on the Tower of Hanoi (TOH) Task

Correlation	Lesion patients				Students			
	Weak TOH performance ^a		Strong TOH performance ^b		Weak TOH performance ^a		Strong TOH performance ^b	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Decision time and perceived task difficulty	.06 _a	.21	.36 _b	.43	.33 _c	.29	.38 _{b,c}	.16
Decision time and rated certainty	-.04 _a	.19	-.37 _b	.42	-.29 _c	.26	-.29 _{b,c}	.31

Note. The numbers represent Fisher's Zs. Means in the same row that do not share a common subscript differ at $p < .05$ in planned single contrasts (t tests). Student participants were randomly assigned to the weak versus strong TOH control groups.

^a $n = 19$. ^b $n = 7$.

of the four groups (FL, NFL, CFL, CNFL), we found that the FL group ($M = .12$, $SD = .25$, $n = 17$) showed a significantly weaker mean Z than the respective student control group ($M = .38$, $SD = .30$, $n = 17$), $t(33) = 2.81$, $p < .01$, whereas the NFL group ($M = .18$, $SD = .39$, $n = 12$) did not differ significantly from the respective student control group ($M = .35$, $SD = .34$, $n = 12$), $t(22) = 1.17$, ns (see Table 1). Moreover, we checked for the homogeneity of variances of the Zs, but no difference between groups was found—Levene's test for homogeneity: $F(3, 55) = 1.17$, ns .

The relation between certainty ratings and decision times. For each of the four groups, we computed mean Fisher's Zs following the same procedure as described above. The FL group ($M = -.08$, $SD = .30$, $n = 18$) tended to show a significantly smaller negative relation between certainty ratings and decision times than the respective student control group ($M = -.26$, $SD = .27$, $n = 18$), $t(34) = 1.89$, $p = .07$. No differences were observed between the NFL group ($M = -.24$, $SD = .33$, $n = 12$) and the respective student control group ($M = -.23$, $SD = .25$, $n = 12$). Both groups showed a clear negative relation between decision times and certainty ratings, $t(22) = 0.05$, ns (see Table 1). Again, Levene's test showed homogeneity of variances in the four groups, $F(3, 56) = 0.02$, ns .

Grouping Lesion Patients by Their Tower of Hanoi (TOH) Performance

The hospital files identified patients as either weak or strong performers on the TOH task. When we analyzed the relation between decision times and perceived task difficulty, we observed no relation in the weak performing group ($n = 19$, mean $Z = .06$, $SD = .21$) and a strong positive relation in the strong performing group ($n = 7$, mean $Z = .36$, $SD = .43$; see Table 2). The difference between the mean Zs was statistically significant, $t(24) = 2.44$, $p < .05$. When comparing the strong performing patients with a randomly selected student control group of the same size ($n = 7$, mean $Z = .38$, $SD = .16$), we observed no signif-

icant difference, $t(12) = 0.12$, ns . A significant difference emerged, however, when patients showing a weak performance on the TOH task were compared with a randomly selected control group of 19 university students (mean $Z = .33$, $SD = .29$), $t(36) = 3.35$, $p < .01$.

With respect to the relation between decision times and rated certainty, the comparison of patients with weak and strong performances on the TOH task revealed a similar pattern of data. As can be seen in Table 2, patients with weak performances ($n = 19$, mean $Z = -.04$, $SD = .19$) showed no meaningful relation, whereas patients with strong performances ($n = 7$, mean $Z = -.37$, $SD = .42$) showed a marked negative relation, $t(24) = 2.83$, $p < .01$.¹ Again, random samples from the student control group were compared with the two patient groups. Patients with strong performances on the TOH task did not differ from a student control group of the same sample size (mean $Z = -.30$, $SD = .31$), $t(12) = 0.36$, ns . However, patients with weak performances on the TOH task differed significantly from the student control group (mean $Z = -.29$, $SD = .26$), $t(36) = 3.48$, $p < .01$. These findings suggest that the TOH task and our decision task may rely on similar processes of conscious action control.

Discussion

Whereas both university students and patients with non-frontal brain lesions evidenced a positive relation between perceived problem difficulty and decision time as well as a negative relation between decision certainty and decision time, no such relations were observed in patients with lesions in the frontal cortex. Assuming that difficult deci-

¹ Because of the inhomogeneity of variances (Levene's test: $F = 8.87$, $p < .01$) and the difference in sample size, we suspected that this t test would not be reliable and therefore an additional Mann-Whitney U test was performed. Mean rank was 15.32 in the group of patients with defective deliberative planning and 8.57 in the group of patients with intact deliberative planning, $U = 32.0$, $z = -1.99$, $p < .05$.

sions are commonly associated with more intensive deliberation than are easy decisions, the lack of a relation between decision time and perceived problem difficulty as well as between decision time and rated certainty as observed in the FL group suggests that these patients failed to engage in intensive deliberation.

This conclusion is supported by the lack of a relation between perceived problem difficulty and decision time as well as between decision certainty and decision time, particularly in those lesion patients with weak TOH performances. Patients with strong TOH performances produced a pattern of results similar to a random sample of university students. These findings also suggest that the mental processes required to successfully perform the TOH task (at least those at the early stages of performance) are similar to the processes of conscious deliberation that precede behavioral choices in everyday life.

Any form of deliberation starts with the encoding of relevant information, and, because there is evidence for encoding and retrieval deficiencies in patients with frontal brain lesions (e.g., concerning source memory [Janowsky, Shimamura, & Squire, 1989], temporal organization of memory [Fuster, 1989; Johnson, O'Connor, & Cantor, 1997], and monitoring of encoding and retrieval [Stuss & Benson, 1986]), encoding of the relevant information itself rather than deliberation may have been impaired in the present study. The pattern of data, however, speaks against this view because patients with frontal brain lesions did not differ from the other groups of participants in terms of the perceived difficulty of the decision problems. Although patients with frontal lesions were sensitive to the difficulty levels of the decision problems, they failed to adjust the amount of deliberation. In line with our interpretation of the present data, Saver and Damasio (1991) observed that in tasks of decision making, frontal lobe patients are not deficient in the encoding and retrieval of information. Further support comes from the classic findings of a dissociation between cognition and action in some patients with frontal brain lesions who successfully repeat received instructions and provide the correct verbal response but fail to produce the respective behavior (Milner, 1963; Stuss, Alexander, & Benson, 1997).

Even though other deficiencies, such as an impairment in affective evaluation (Bechara, Damasio, Tranel, & Damasio, 1997; Damasio, 1995, 1997; Mesulam, 1998) and the failure to energize oneself to form a goal commitment (Al-Adawi, Powell, & Greenwood, 1998), may contribute to poor deliberation in patients with frontal brain lesions, insufficient cognitive weighing of the decision alternatives at hand may be most detrimental. As Knight, Grabowecky, and Scabini (1995) have pointed out, the capability to generate and evaluate counterfactuals is strongly hampered in patients with frontal lobe lesions. Accordingly, patients with frontal brain lesions in our study failed to become more intensively involved with weighing pros and cons in relation to an increase in perceived difficulty of the decision problem at hand. Our data thus confirm that lesions in areas of the frontal lobes lead to defective deliberation. Reflective action control in the sense of effortful goal selection seems

to rely on processes that are subsumed in the frontal lobes' executive functions of control.

Study 2: Reflexive Action Control

Gollwitzer (1993, 1999) described how people can automatize the initiation of goal-directed actions by forming implementation intentions. Automatic action initiation is commonly found with habitual behaviors in which the same behavior has repeatedly and consistently been performed in the very same situation. Forming implementation intentions shortcuts this learning process (Gollwitzer & Brandstätter, 1997; Gollwitzer & Schaal, 1998) by simply linking critical anticipated situational cues to the intended goal-directed behavior ("If situation *y* arises, I will perform the goal-directed behavior *z*"). By forming a decisive plan ahead of time, action control becomes reflexive and does not require conscious deliberation once the critical situation is encountered.

Because patients with frontal brain lesions are easily distracted by environmental cues that trigger the execution of routine behaviors (Karnath et al., 1991), they should benefit from having formed implementation intentions. Furthermore, not only do frontal lobe lesions seem to spare the automatic initiation of behavior, but new habits can still be established through classical conditioning procedures (e.g., Daum, Channon, Polkey, & Gray, 1991; Doyon et al., 1998) as long as the task does not require deliberative thinking or decision making (B. Levine, Stuss, & Milberg, 1997; Petrides, 1997). Thus, when patients with frontal lobe lesions are helped to form implementation intentions, the positive consequences in terms of automatic action initiation should prevail. In other words, implementation intentions once formed should effectively control their behavior.

We used a dual-task paradigm that allowed us to assess the immediacy and efficiency of action initiation—two vital features of the automatic, reflexive control of action (Bargh, 1997). Immediacy was tested in a Go–NoGo task by measuring the speed of a button-press response. To assess efficiency, we manipulated the difficulty of the primary task (a motor tracking task), which also allowed us to observe the speed of responses under low versus high mental load conditions.

We predicted that when implementation intentions are formed, the initiation of the intended response should be facilitated in all groups of participants (patients with frontal lobe lesions, patients with nonfrontal lobe lesions, and university students) to the same degree. Moreover, we expected this effect to be independent of the difficulty of the competing task. According to classic findings from dual-task research (Heuer, 1996), there should be less interference between the button-press responses in the Go–NoGo task and the competing tracking task if the button-press responses are automatically controlled by implementation intentions.

Method

Participants

Of the 34 brain-injured participants, 20 had frontal lobe lesions (8 women, 12 men) and 14 had nonfrontal lobe lesions (8