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Motor initiation and execution in patients with conversion paralysis

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Abstract

Motor initiation and motor execution in four patients with conversion paralysis were investigated in a non-affected motor modality (speech). In line with the hypothesis of dissociated control in conversion disorder [Cognit. Neuropsychiatry 8 (1) (2001) 21] motor initiation, but not response duration, was expected to be impaired. The motor initiation times (reaction time: RT) and motor execution times (response duration: RD) were compared on four RT-tasks that required the production of a verbal response: a simple choice RT-task, a mental letter rotation task, and an implicit and an explicit mental hand rotation task. Because conversion disorder is expected to primarily involve an impairment in the initiation of movement, we expected the following task characteristics to uniquely affect RT and not RD: type of instruction (implicit versus explicit instructed imagery), angle of rotation, and target arm (affected versus non-affected arm). The results indeed showed the task characteristics to significantly affect the participants' RT and not their RD. It was concluded that conversion paralysis is associated with a specific impairment in the explicit initiation of processes with a spatial and motor component. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Conversion symptoms are characterized by dissociation between lower-level and higher-level information processing. According to Kihlstrom's dissociation theory of conversion disorder the explicit or higher-level intentional information processes are impaired, whereas the implicit or lower-level automatic processes remain intact (Kihlstrom, 1992a,b). The findings of a recent motor imagery study in six patients with conversion paralysis have supported this theory (Roelofs et al., 2001). Motor imagery or mental movement is important for the planning and preparation of movement (see Jeannerod, 1997) and activates brain structures that greatly overlap those activated during real movement (Decety et al., 1994; Kosslyn, Digirolamo, Thompson, & Alpert, 1998; Parsons et al., 1995; Stephan et al., 1995). In the motor imagery study by Roelofs and colleagues, mental movement was both implicitly and explicitly evoked. In a hand judgement task, participants were presented with rotated pictures of left and right hands and instructed to identify as quickly as possible which hand was shown by saying 'left' or 'right'. Several cognitive studies (Dominey, Decety, Broussolle, Chazot, & Jeannerod, 1995; Parsons, 1987, 1994) and brain imaging studies (Parsons & Fox, 1998; Parsons et al., 1995; Parsons, Gabrieli, Phelps, & Gazzaniga, 1998) have shown that this task implicitly evokes mental rotations of the participant's limb. It is, therefore, called the implicit motor imagery task. In the explicit motor imagery task of the study of Roelofs et al., participants were again presented with the pictures of hands but now with the explicit instruction to mentally move their own hands from a neutral starting position into the target position and to say 'yes' when the target position had been reached. Reaction times were recorded using voice-key registration.

In patients with neurological motor pathology such as Parkinson's disease, the reaction time (RT) profiles of an implicit motor imagery task were highly similar to the RT-profiles for explicitly instructed motor imagery (see Dominey et al., 1995). For patients with conversion paralysis, however, Roelofs et al. (2001) found that, in accordance with dissociation theory, motor imagery is more severely impaired when it is explicitly instructed. Compared to controls, patients were significantly slower on the explicit motor imagery task when mentally moving their most severely affected arm. This effect was absent when motor imagery was implicitly evoked. The findings suggested that motor processing in conversion disorder is especially impaired when it is intentional. Furthermore, the results showed patients to be slower than controls when the angle of rotation increased in the mental hand rotation tasks and also in an additional mental letter rotation task. Finally, although patients were also slower on a simple reaction time task, the relative slowing was larger for tasks that strongly depended on intentionality (explicit motor imagery task) and mental rotation (larger rotation angles). These findings indicated conversion paralysis to primarily involve a specific impairment in the explicit initiation of motor processes. It was therefore suggested that in conversion paralysis dissociation, as a reaction to prolonged stress or psychological trauma, involves a dissociation of higher- and lower-level motor control. The additional finding that patients were slowed not only on the motor imagery tasks but also on a simple reaction time task suggested that this dissociation not only is symptom specific but also involves a more widespread disconnection of lower- and higher-level motor control (Roelofs et al., 2001). Such a dissociation between higher- and lower-level motor control fits in with widespread hierarchical models of motor functioning (see e.g. Gazzaniga, Ivry, & Mangun, 1998) in which the components of motor processing form a hierarchy with multiple levels of control. At the highest level are premotor and association areas. Processing within these regions is critical for planning an action based on perceptual information, past experience and future goals. The role of the motor cortex and brainstem structures, with the assistance of the cerebellum and basal ganglia, is to translate the action goals into a movement. Lower-level action control within these structures can occur without higher-level action control. Shallice and Burgess (1998) have also developed a model allowing dissociations between higher-level and lower-level action control. They describe a higher-level executive control system, the supervisory attentional system (SAS) that, for the greater part, is based in the frontal cortex. It is conceived of as monitoring ongoing activity and modulating behavior when established automatic routines are not sufficient, as, for instance, in novel situations. It is suggested that in patients with conversion paralysis movements fail, especially when higher-level SAS control is involved (Oakley, 1999). Such a dissociation of lower-level and higher-level (SAS) control is assumed to predominantly affect performance when tasks greatly appeal to the conscious initiation of movement or the integration of complex cognitive, sensory and motor functions (Roelofs et al., 2001).

Although two case studies (Lauerma, 1993; Marshall, Halligan, Fink, Wade, & Frackowiak, 1997) offered some indications for a symptom-specific impairment in the voluntary initiation of movement in conversion paralysis, there are no studies available addressing the suggested possibility of a more widespread, symptom-independent dissociation between lower-level and higher-level motor control in patients with conversion paralysis. The latter can be studied by comparing motor initiation to motor execution in a non-affected motor modality. If conversion paralysis indeed involves a specific impairment in the initiation of movement, task-specific factors, such as angle of rotation (in the mental hand and letter rotation tasks), type of instruction (implicitly versus explicitly instructed mental hand rotations) and target arm (best versus worst functioning arm), should only affect the initiation of movement and not the execution of movement. However, several studies, separating motor initiation from motor execution, have shown that cognitive processes, such as memory retrieval and spatial attunation, influence not only motor intiation time but also motor execution time (Fitts, 1954; Sternberg, Monsell, Knoll, & Wright, 1978; Sternberg, Wright, Knoll, & Monsell, 1980). The latter authors, for example, showed that the time taken to pronounce a word increased as the length of the sequence in which the words were presented increased. It is therefore important to find out whether angle of rotation, type of instruction and target arm also have a slowing effect on the motor execution of patients with conversion paralysis. If the latter is the case, the slowing observed in conversion patients would reflect a more general, aspecific slowing, such as observed for patients with depression (White, Myerson, & Hale, 1997), and not a specific slowing of the initiation of movements as proposed by the dissociation hypothesis.

Table 1
Stimuli per task

	Task	Stimuli
1	Simple choice RT	48 figures [2×24 (circle, square)]
2	Mental letter rotation	64 letters [$2 \times (8$ angles $\times 2$(mirror, normal) $\times 2$(R, F))]
3	Implicit hand rotation	64 hands [$2 \times (8$ angles $\times 2$(left, right) $\times 2$(back, palm))]
4	Explicit hand rotation	64 hands [$2 \times (8$ angles $\times 2$(left, right) $\times 2$(back, palm))]

Note: In Task 1 (simple choice RT-task) participants responded by saying 'circle' or 'square' as soon as a circle or square appeared on the computer screen. In Task 2 (mental letter rotation task) participants were presented with the letters R and F in various rotations. Participants were to determine whether the letters were presented in a normal or mirrored way by saying 'normal' or 'mirror'. In Task 3 (implicit hand rotation task) participants responded by saying either 'left' or 'right' depending on the identity of the the hand shown in the picture on the screen. In Task 4 (explicit hand rotation task) participants responded by saying 'yes' as soon as they had mentally rotated their own hand into the target position as shown on the screen.

The purpose of the present study is to investigate whether the slowing due to a large angle of rotation, explicit instruction and the use of the affected arm, found for patients with conversion paralysis in the study of Roelofs et al. (2001), reflects a specific slowing of motor initiation processes and not of motor execution processes. To test this hypothesis we needed to separate motor initiation from motor execution. Because patients with conversion paralysis typically cannot move their affected limb and because we wanted to study general effects in motor processing that are manifested not only in the paralyzed modality, we investigated motor initiation and execution in a non-affected motor modality, in this study speech production. The reaction time tasks, i.e. three mental rotation tasks and a simple reaction time task (see Table 1), used in the study by Roelofs et al. (2001) all required the production of a verbal response, which is a voluntary movement in itself. We therefore used these tasks again in the present study to collect data on motor initiation and motor execution under the same experimental conditions. Motor initiation involves motor planning (retrieval of a stored motor program) and motor preparation (translation of the abstract task specifications into specific muscle commands) (Gazzaniga, Ivry & Mangun, 1998; Sternberg et al., 1978) and will be measured using RT. Motor execution involves the activation and coordination of the musculature, which will give rise to movement, in this study speech. Motor execution will be measured using speech duration (response duration: RD). In comparing the RT and RD of patients and controls on the four tasks, we expected – in line with the dissociated control theory of conversion disorder – rotation angle, type of instruction and target arm to uniquely affect RT but not RD.

2. Method

Response duration of verbal responses was measured and RD-effects were compared to RT-effects in four reaction time tasks. All tasks required the participants to verbally respond to stimuli presented on a computer screen as quickly and as accurately as possible. Table 1 gives an overview of the stimuli presented in each task as well as a brief description of the tasks. For a more extended description of the procedures see Roelofs et al. (2001). The sound tracks of the video recordings of the experimental sessions were digitized at a rate of 22 050 Hz (16-bit resolution). The resulting digital sound files were normalized and subsequently noise was reduced by 20 dB with a high shelf cut-off frequency of 7000 Hz using Sound Forgel [1] 4.5 for Windows 95. Two trained language and speech pathologists, who had no knowledge of the research question and the clinical status of the participants, measured the speech time per word using 'Praat' (Boersma & Weenink, 1992–2000), a software package for speech analyses.

2.1. Participants

Of the six patients with conversion paralysis and the six healthy controls who had already participated in an earlier motor imagery study (Roelofs et al., 2001), four patients and six controls could be included in the present study because high-quality video recordings of the motor imagery sessions were available. The patients were all right-handed females who had either full or partial paralysis in one or more limbs as the major symptom. The patients had been referred for either in- or outpatient treatment to a general psychiatric hospital specialized in the treatment of conversion disorders. A psychiatrist screened the patients using the criteria of the DSM-IV (American Psychiatric Association, 1994). A complete neurological and somatic screening was performed on all patients. When necessary, additional diagnostic techniques such as serial computed tomography (CT) brain scans or magnetic resonance imaging (MRI) were employed. Whenever the somatic or neurological screening revealed any abnormalities the patients were not diagnosed with conversion disorder and were excluded from the study. A psychological interview and neuropsychological tests had shown all the patients to have normal intellectual functions. They were screened for axis-1 comorbidity using the Structured Clinical Interview for DSM-IV Axis I Disorders (First, Gibbon, Spitzer, & William, 1996). One patient met the criteria for a major depression in remission and used an antidepressant (paroxetine, 20 mg/day). One patient met the criteria for generalized anxiety disorder and used oxazepam (10 mg) on an irregular basis, but had agreed to refrain from taking the drug 10 hours prior to the experiment. Table 2 shows relevant information with respect to the patients' ages and complaints. The control participants were six right-handed females with a mean age of 31.3 years [standard deviation $(SD) = 5.1$] who were recruited via acquaintances and colleagues of the experimenter. The best and the worst functioning arm of all participants were identified. For patients this identification was independently checked and confirmed by the attending physiotherapist and for controls the identification was based on the reaction times on the motor imagery tasks (Tasks 3 and 4) (Roelofs et al., 2001).

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Table 2
Patient information

Patient	Age	Sex	Worst affected arm	Duration of complaints (months)	Past history of traumatic experiences	Events preceeding symptom onset
1	19	F	Left	9	–	Loss of friend
2	44	F	Right	18	Incest	Trauma processing in psychotherapy
3	26	F	Right	8	Incest	–
4	47	F	Left	40	–	Hospital admission due to depression

2.2. Analyses

The RT-profiles and the RD-profiles of patients and controls were compared on the four tasks (see Table 1). On the simple choice RT-task (Task 1) we used simple t-tests for independent samples. In the mental rotation tasks (Tasks 2–4) not the direction but the length of rotation was of interest for the present study. Because the 45° and 315°, 90° and 270°, and 135° and 225° rotations equally differ from the 0° position, the data were collapsed for each pair of angles. This resulted in five orientation differences (OD) of 0°, 45°, 90°, 135°, and 180°. For each participant the mean RD and RT of the correct responses were calculated per OD for every task. On each task, RDs and RTs greater than two SDs from the individual mean RD and RT per OD (and per limb in Tasks 3 and 4) were attributed to distraction or a loss of attention and therefore excluded from the analyses.

Because RT linearly increases as a function of rotation angle (Shepard & Cooper, 1982) it is common to use regression analysis as a method for data reduction in mental rotation tasks. The individual regression coefficients (intercept and slope) were calculated for the best and the worst functioning arm on the motor imagery tasks. The slope of the regression function is the relative RT increase per rotation degree, which provides an estimate of the rate at which the mental manipulation is carried out. The intercept is the estimated RT without rotation load. On the motor imagery tasks the mean slopes and intercepts of patients' and controls' RT and RD were compared using one-tailed analyses of variance (ANOVAs) with Group (patients, controls) as between-subject factor and Arm (best, worst functioning) as within-subject factor.

3. Results

3.1. Interrater reliability

The interrater reliabilities of the RDs per word, estimated by the two assessors, were calculated using correlations over 299 randomly selected trials across the four tasks (approximately 10% of the total amount of trials). The mean RDs (in ms) per task for assessors 1 and 2 were 556 (SD = 45) and 549 (SD = 42) in Task 1; 573

(SD = 49) and 568 (SD = 57) in Task 2; 487 (SD = 44) and 499 (SD = 43) in Task 3; and 364 (SD = 62) and 369 (SD = 59) in Task 4, respectively. The interrater reliabilities (r) for the words 'cirkel' (circle) and 'vierkant' (square) as measured for the simple choice RT-task (Task 1) were 0.88 and 0.79, respectively. For the words 'spiegel' (mirror) and 'normaal' (normal) of the mental letter rotation task (Task 2), $r = 0.81$ and 0.79, respectively. For the words 'links' (left) and 'rechts' (right) of the implicit hand rotation task (Task 3), $r = 0.92$ and 0.71, respectively. And for the word 'ja' (yes) of the explicit hand rotation task (Task 4) $r = 0.78$ ($p < 0.001$ for all r's).

3.2. Task 1: Simple choice RT-task

An ANOVA with factor Group (patients, controls) showed that the mean reaction times (RTs in ms) of patients (717, SD = 218) were significantly longer than the mean RTs of controls (495, SD = 79) on the simple choice RT-task [$F(1,8) = 5.45$, $p < 0.05$]. As far as RD is concerned, the patients' mean RDs (654, SD = 75) did not significantly differ from the RDs of the controls (587, SD = 65) [$F(1,8) = 2.22$, $p = 0.18$].

3.3. Task 2: Mental letter rotation task

The means and standard deviations of both RT and RD are shown in Table 3. The mean R^2 of the individual regression lines for RT was 0.66 for controls and 0.64 for patients. The R^2s for RD were 0.40 and 0.34, respectively. An ANOVA with factor Group (patients, controls) showed significant group differences for both the RT-intercepts [$F(1,8) = 5.88$, $p < 0.05$] and the RT-slopes [$F(1,8) = 4.78$, $p < 0.05$]. There were, however, no such group effects either for the RD-intercepts [$F(1,8) = 0.63$, $p = 0.23$] or for the RD-slopes [$F(1,8) = 2.33$, $p = 0.08$]. Thus, the significant effects of group and angle of rotation on RT were not found for RD (see Fig. 1).

3.4. Task 3: Implicit hand rotation task

The means and standard deviations of both RT and RD are shown in Table 4.

The mean R^2 for the controls' regression lines for RT was 0.70 for the best and 0.54 for the worst functioning arm. For patients the mean R^2s for RT were

Table 3
Means and standard deviations (ms) of regression coefficients associated with RD and RT on the mental letter rotation task

		RT	RD
Intercept	Patients	937 (175)	572 (82)
	Controls	743 (78)	541 (41)
Slope	Patients	2.77 (1.37)	0.06 (0.04)
	Controls	1.36 (0.69)	0.14 (0.10)

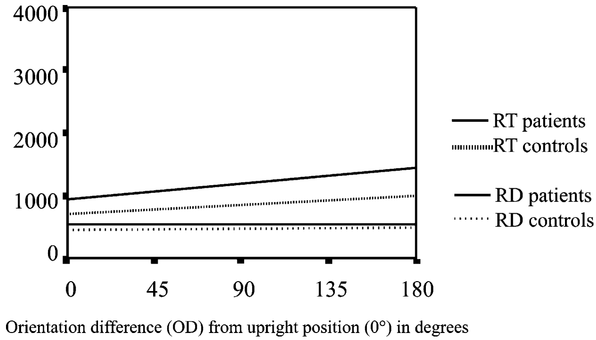

Fig. 1. RT and RD (in ms) of patients and controls on the mental letter rotation task (2).

Table 4
Means and standard deviations (ms) of regression coefficients associated with RD and RT on the implicit hand rotation task

		Arm worst		Arm best	
		RT	RD	RT	RD
Intercept	Patients	1291 (323)	571 (92)	1459 (606)	608 (108)
	Controls	979 (247)	532 (46)	942 (257)	543 (58)
Slope	Patients	6.8 (0.76)	−0.03 (0.10)	3.8 (4.77)	−0.18 (0.39)
	Controls	2.51 (1.54)	0.03 (0.06)	2.21 (1.24)	−0.03 (0.19)

0.60 and 0.71, respectively. For RD, the mean R^2 for the controls' regression lines was 0.38 for the best and 0.31 for the worst functioning arm. For patients the mean R^2s for RD were 0.30 and 0.32, respectively.

Two-way ANOVAs with Arm (best, worst) as within-subject factor and Group as between-subject factor showed the following results for RT. On the RT-intercept there was a significant main effect for Group [$F(1,16) = 6.43$, $p < 0.05$] but not for Arm [$F(1,16) = 0.16$, $p = 0.35$]. There was no significant Group × Arm interaction [$F(1,16) = 0.40$, $p = 0.27$]. Also on the RT-slope there was a significant effect for Group [$F(1,16) = 7.35$, $p < 0.01$] but not for Arm [$F(1,16) = 2.31$, $p = 0.07$] or Group × Arm [$F(1,16) = 1.53$, $p = 0.12$]. As far as RD is concerned, on the RD-intercept there were no significant effects for Group [$F(1,16) = 2.31$, $p = 0.07$], Arm [$F(1,16) = 0.51$, $p = 0.24$] or Group × Arm [$F(1,16) = 0.15$, $p = 0.35$]. On the RD-slope there were also no significant effects for Group [$F(1,16) = 1.27$, $p = 0.14$], Arm [$F(1,16) = 1.27$, $p = 0.14$] or Group × Arm [$F(1,16) = 0.20$, $p = 0.33$].

In sum, on the implicit hand rotation task patients have larger intercepts for RT and not for RD. Furthermore, the RT-increase per degree of rotation was larger in patients than in controls, whereas the RD-increase per degree of rotation was slightly smaller in patients than in controls. Thus, the effects of group and angle of rotation were more pronounced for RT than for RD (see Fig. 2).

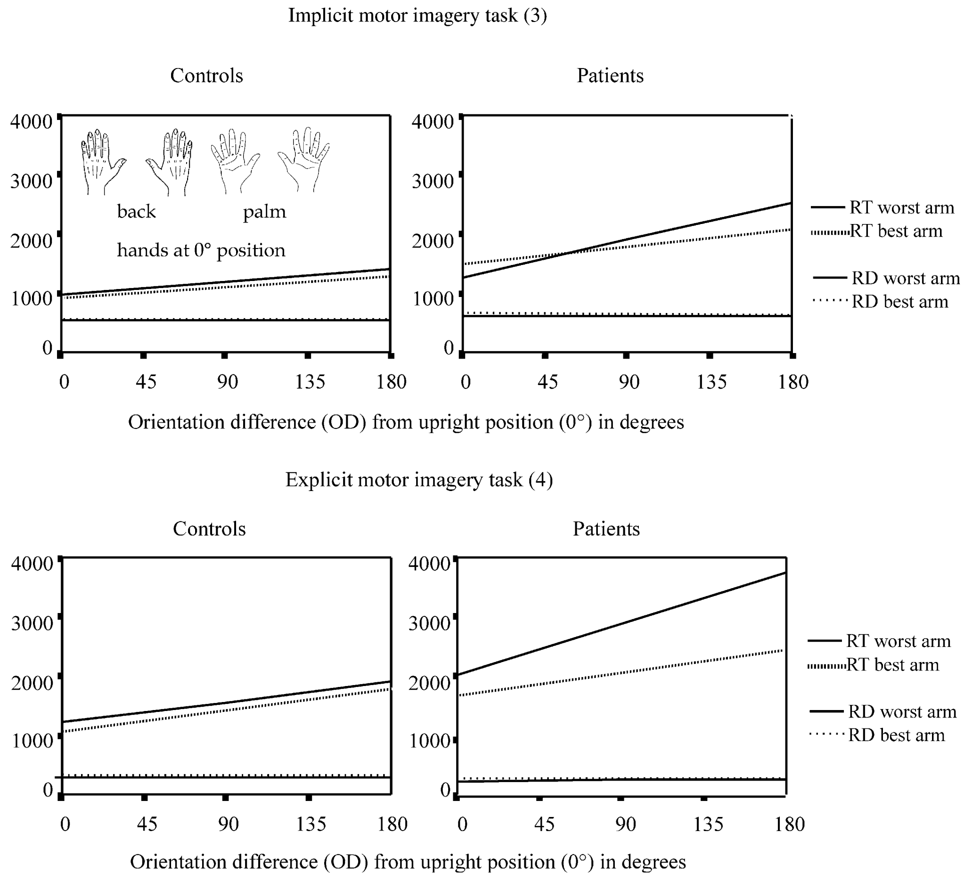

Fig. 2. RT and RD (in ms) for the best and the worst functioning arm on the mental hand rotation tasks.

3.5. Task 4: Explicit hand rotation task

The means and standard deviations of both RT and RD are shown in Table 5.

The mean R^2 for the controls' regression lines for RT was 0.69 for the best and 0.88 for the worst arm. For patients the mean R^2s for RT were 0.79 and 0.76, respectively. For RD, the mean R^2 for the controls' regression lines was 0.24 for the best and 0.38 for the worst arm. And for patients the mean R^2s for RD were 0.40 and 0.33, respectively.

Two-way ANOVAs with Arm (best, worst) as within-subject factor and Group as between-subject factor showed the following results for RT. On the RT-intercept there was a significant main effect for Group [$F(1,16) = 8.88$, $p < 0.01$] but not for Arm [$F(1,16) = 0.66$, $p = 0.21$]. There was no Group × Arm interaction [$F(1,16) = 0.16$, $p = 0.35$]. On the RT-slope there were significant effects for Group [$F(1,16) = 3.57$, $p < 0.05$], Arm [$F(1,16) = 2.85$, $p < 0.05$] and Group × Arm

Table 5
Means and standard deviations (ms) of regression coefficients associated with RD and RT on the explicit hand rotation task

		Arm worst		Arm best	
		RT	RD	RT	RD
Intercept	Patients	1960 (445)	239 (46)	1690 (819)	302 (37)
	Controls	1208 (310)	297 (42)	1115 (293)	300 (50)
Slope	Patients	10.23 (6.37)	−0.13 (0.25)	4.73 (1.91)	0.05 (0.18)
	Controls	4.06 (2.57)	0.05 (0.21)	4.01 (3.12)	0.03 (0.06)

[$F(1,16) = 2.83$, $p < 0.05$]. As far as RD is concerned, on the RD-intercept there were no significant main effects for Group [$F(1,16) = 0.03$, $p = 0.48$], Arm [$F(1,16) = 0.10$, $p = 0.38$] or Group × Arm [$F(1,16) = 0.02$, $p = 0.49$]. The RD-slope also showed no effects for Group [$F(1,16) = 0.37$, $p = 0.28$], Arm [$F(1,16) = 0.38$, $p = 0.27$] or Group × Arm [$F(1,16) = 0.12$, $p = 0.37$].

In sum, like the implicit hand rotation task, the explicit task showed significant RT-effects of Group on the slope and on the intercept. Moreover, in contrast to the implicit task, the explicit task showed significant effects on the RT-slope of Arm. There was a significant interaction between Group and Arm indicating that patients were slower in mentally rotating their worst functioning arm. What is most important is that, as hypothesized, there were no such effects for Group, angle of rotation, or target arm on RD. Finally, it should be noted that the effects for RT were more pronounced in the explicit hand rotation task than in the implicit hand rotation task while there was no such difference between implicitly and explicitly instructed mental hand rotations for RD (see Fig. 2).

4. Discussion and conclusion

The reaction times of patients with conversion paralysis had, in an earlier study, shown to be affected by task characteristics such as angle of rotation, type of instruction (implicitly versus explicitly instructed motor imagery) and target arm (best versus worst functioning arm) (Roelofs et al., 2001). In the present study it was investigated whether the slowing due to these factors is unique to motor initiation (reaction time, RT) or whether it involves a more general slowing that also manifests itself in motor execution (response duration, RD). We expected to find a specific slowing in the motor initiation. Accordingly, unlike RT, RD was hypothesized to show no effects of angle of rotation, target arm and instruction.

The results showed that the RTs of patients with conversion paralysis were slower than the RTs of controls on all tasks. Patients were also somewhat slower in their overall RD than controls, but this difference was not significant in any of the tasks. The relative slowing of the patients was over 2.5 times larger for RT than for RD. These results indicate that, in patients, the relative impairment in motor initiation is considerably greater than the impairment in motor execution. Furthermore, there was a significant RT effect of angle of rotation in Tasks 2–4 and of arm in Task 4. Unlike RT, RD showed no such specific slowing effect due to rotation angle or arm. Thus the mental rotation and the use of the most severely affected arm only influenced the motor initiation and not the motor execution. Also in contrast to RT, RD did not show larger effects of arm and rotation angle in the explicit hand rotation task, compared to the implicit hand rotation task. These results support our hypothesis that patients with conversion paralysis show a specific impairment in the explicit initiation of processes with a spatial and motor component.

The specific disturbances in the intentional or explicit initiation of movement suggest that conversion disorder is associated with an impaired linkage between higher-level and lower-level information processes. This is in agreement with the theory of Oakley (1999) of dissociated control in conversion disorder. Oakley (1999) argued that in conversion paralysis internal influences (such as autosuggestion) on the SAS (Shallice & Burgess, 1998) can result in an inhibition of movement. Especially when movement is intentionally generated, and involves to a certain extent SAS involvement, internal and external influences on the SAS are likely to affect movement. The slowing in motor initiation observed in the present study, as reflected by the larger RTs on all performed tasks, is likely to be a disturbance of the intentional control as part of the whole information processing system. It is a widely recognized phenomenon that under severe psychological stress high cortical abilities, such as concentration and the voluntary focus of attention, diminish. In terms of Shallice's model, higher-level SAS control is likely to decrease under the influence of severe trauma or prolonged exposure to stressful situations. Under these circumstances, human information processing tends to fall back on lower-level processes, which allows a person to function when hardly any explicit initiation is required. As a result, conscious control over the system is weakened and the integrity of the information processing system, which normally shows a fluent co-operation, is disturbed. In these dissociated conditions, initiation of motor processes is slowed, especially when motor performance requires a high degree of intentionality. Although it remains to be investigated, it is not unlikely that the specific initiation slowing observed in the present study will also be found to be manifest in tasks that do not have a spatial component, such as semantic tasks.

The idea that conversion disorder is associated with an impaired linkage between higher-level and lower-level information processes is also in agreement with a brain mapping study of Marshall et al. (1997) in which a patient with conversion paralysis showed no activity in the primary motor cortex (M1) when she attempted to move. The decrease in activation of the M1 was accompanied by an increased activation of the orbito-frontal cortex and the anterior cingulate cortex, suggesting an impairment when high cognitive control processes are involved.

A possible objection to the operationalization of motor execution and motor initiation in the present study is that RD may be a less sensitive measure than RT. Speech duration has, however, frequently been shown to be effected by cognitive factors (see e.g. Sternberg et al., 1978, 1980). And also in these studies effects in speech duration were shown for short (2–3 letter) utterances. Another objection may be that the words to be pronounced were different for the separate tasks. The word 'ja' (yes) of the explicit hand rotation task is shorter than the words 'links' and 'rechts' (left and right) of the implicit hand rotation task and may be less sensitive in that it shows less variability. We chose not to use the words 'left' and 'right' in the explicit task to prevent the subjects from again focussing on the left/right decision, which could have distracted them from focussing on mentally moving their arms as quickly and accurately as possible. To see whether the word yes indeed showed less variability we checked the response words across all experimental tasks (see Table 1) and compared the SDs of the RDs of the shortest word and the longest words. The SDs of the shortest (two-letter) word ranged from 12% to 20% and those of the longest (seven-letter) words from 8% to 12%. This indicates that the shortest word showed at least as much variability as the longest words and was thus likely to be equally sensitive to subject and task factors.

In conclusion, the finding that the patients' RT and not their RD was slowed in a non-affected motor modality suggests that conversion paralysis is characterized not so much by a general or task-unspecific slowing as by a specific slowing of explicit motor initiation. It should be noted that this report concerns fundamental motor processes observed in patients with conversion paralysis and not necessarily the mechanisms behind the development of conversion paralysis. The dissociation between higher- and lower-level motor processes may, however, constitute a predisposition for the final development of motor conversion symptoms. This view is supported by previous findings that indicate that conversion patients show an increased capacity to evoke dissociations between implicit and explicit motor, sensory and cognitive processes upon hypnotic suggestion and that this increased suggestibility is related to symptom severity (Roelofs et al., in press). But the fact that a conversion paralysis eventually develops in one specific limb and not in another may be due to completely different factors, such as the perceived presence of a weak spot somewhere on the body due to previous disease, iatrogenic suggestion due to repeated examinations by a physician, the symbolic meaning of the symptom in relation to previous trauma, or any other suggestive or reinforcing factor in the social environment. Unfortunately, the possible role of these factors has not been clarified yet.

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