Reduced awareness for apraxic deficits in left hemisphere stroke

Kusch, M.[1,2*], Gillessen, S.[1*], Saliger, J.[3], Karbe, H.[3], Binder, E.[1], Fink, G.R.[1,2], Vossel, S.[2,4§], Weiss, P.H.[1,2§]

[*] Mona Kusch and Sarah Gillessen contributed equally to this work and thus share the first authorship.

[§] Simone Vossel and Peter H. Weiss contributed equally to this work and thus share the senior authorship.

[1]*Department of Neurology, University Hospital Cologne, 50924 Cologne, Germany*

[2]*Cognitive Neuroscience, Institute of Neuroscience & Medicine (INM-3), Research Centre Jülich, 52425 Jülich, Germany*

[3]*Neurological Rehabilitation Centre Godeshöhe, 53177 Bonn, Germany*

[4]*Department of Psychology, University of Cologne, 50931 Cologne, Germany*

Corresponding author:

Mona Kusch, Cognitive Neuroscience, Institute of Neuroscience & Medicine (INM-3), Research Centre Jülich, 52425 Jülich, Germany; phone: +49-2461-61-2073, fax: +49-2461-61-1518, email: mona.kusch@uk-koeln.de

Abstract (224 words)

Objective*:** Reduced awareness for motor or cognitive impairments has mainly been studied in relation to right-hemispheric deficits such as left-sided hemiparesis. However, recent studies suggest that also left hemisphere (LH) stroke can lead to reduced awareness for neurological/ neuropsychological deficits, e.g., aphasia. The aim of the current study was to characterize reduced awareness for apraxic as well as aphasic deficits in patients suffering from LH stroke. ***Methods: After the assessment of apraxia and aphasia patients (n = 32) were asked to rate their performance on a 1-to-5-point rating scale. An UnAwareness Score (UAS) was computed as the difference between the examiners' ratings and self-ratings, resulting in negative scores for patients who overestimated their performance in a given assessment, i.e. exhibited reduced awareness for their stroke-related deficits. ***Results:*** Patients suffering from apraxia (n = 14) and aphasia (n = 16) significantly overestimated their performance in the respective assessment. However, the level of awareness was not generally related to the severity of apraxia and there were no group differences in other variables between patients with full (n = 7) and reduced awareness (n = 7) for apraxic deficits. The reduction of awareness for apraxic deficits did not differ significantly for bucco-facial versus limb gestures. ***Conclusion:*** Data show that LH stroke can not only lead to reduced awareness for aphasic deficits but also for bucco-facial *and* limb apraxia.

Keywords: awareness, apraxia, aphasia, stroke

public significance statement: The current study is one of the first studies investigating reduced awareness for limb *and* bucco-facial apraxia. Our results highlight the importance of the left hemisphere in deficit awareness and have strong implications for the clinical practice of assessing awareness not only after right, but also after left hemisphere damage.

Introduction

Apraxia is a disorder of motor cognition that cannot be accounted for by primary motor, sensory, or aphasic deficits. It is defined as the inability to carry out learned purposeful actions and is commonly observed after LH damage and therefore often accompanied by aphasia (e.g., Dovern, Fink, & Weiss, 2012). Patients with apraxia suffer from deficits in the domains of actual tool use, imitation of gestures, and pantomiming the use of objects leading to relevant impairments in everyday life (Bjørneby & Reinvang, 1985; Giaquinto et al., 1999; Sundet, Finset, & Reinvang, 1988). Apraxic deficits may vary depending on the body part that is affected. Patients can exhibit apraxia related to their limbs (i.e., limb apraxia) or to their face and mouth (i.e., bucco-facial apraxia).

Recently, Canzano, Scandola, Pernigo, Aglioti, and Moro (2014) conducted the first study investigating awareness for apraxic deficits showing that LH damaged patients suffering from bucco-facial apraxia may have reduced awareness for their apraxic deficit. This finding is especially interesting as the reduced awareness for one's own deficits (often also referred to as anosognosia) has been historically associated with right hemisphere (RH) damage and the related syndromes like left-sided hemiparesis (e.g., Babinski, 1914 as translated in Langer & Levine, 2014) or neglect (e.g., Vossel, Weiss, Eschenbeck, Saliger, & Karbe, 2012; Bisiach, Vallar, Perani, Papagno, & Berti, 1986). Consistent with the assumption that the LH may also contribute to awareness, some studies revealed reduced awareness for aphasic deficits after LH lesions (Cocchini, Gregg, Beschin, Dean, & Della Sala, 2010; Kertesz & Benson, 1970). It has been suggested that the differential effect of right and left hemisphere damage on deficits in awareness may be due to a methodological bias (Nurmi & Jehkonen, 2014). Reduced awareness for neurological deficits is usually assessed via structured interviews, which presume intact verbal comprehension and speech production. Consequently, as LH stroke is often associated with aphasia, a major part of patients with LH damage has been excluded from studies investigating deficit awareness (Cutting, 1978;

Nathanson, Bergman, & Gordon, 1952; Stone, Halligan, & Greenwood, 1993; but see Cocchini, Beschin, Fotopoulou, & Sala, 2010; Moro, Pernigo, Zapparoli, Cordioli, & Aglioti, 2011). Cocchini, Beschin, Cameron, Fotopoulou, and Della Sala (2009) compared the prevalence of anosognosia for hemiplegia (AHP) after LH stroke assessed with the classical method, i.e., a structured interview, and with a new method, which reduces language demands by using non-verbal stimuli and a visual rating scale. Interestingly, with the latter assessment more patients with LH stroke could be included in the study (30 vs. 20) and higher prevalence rates of reduced awareness for motor deficits were observed with the new method as compared to the structured interview method (40% vs.10%). These findings provide first evidence that reduced awareness for neurological deficits may not exclusively occur after lesions of the right hemisphere (RH) and that the prevalence and clinical relevance of reduced awareness for neurological deficits after LH stroke may have been underestimated in the past.

To date, the level of awareness for apraxia has only been investigated in patients suffering from bucco-facial apraxia (Canzano et al., 2014). As two separable praxis systems seem to underlie bucco-facial and limb apraxia (Raade, Rothi, & Heilman, 1991), it is mandatory to investigate whether patients suffering from limb apraxia also show reduced awareness for their apraxic deficits. Therefore, the aims of the current study were to i) investigate awareness for apraxic deficits in a larger group of LH stroke patients, ii) compare the reduction of awareness for apraxic deficits involving limb versus bucco-facial gestures, and iii) characterize the relationship between reduced awareness for aphasic and apraxic deficits.

Methods

Patients

A total of 43 patients with unilateral LH stroke were consecutively recruited during the sub-acute or chronic stage from the Department of Neurology, University Hospital Cologne (n = 24) and the Neurological Rehabilitation Centre, Bonn (n = 19). Ten patients were excluded after enrolment because of additional right-hemispheric lesion (n = 1), left-handedness (n = 2) and severity of aphasia (n = 5). Two patients were excluded because of visual problems: One patient had a macular degeneration of both eyes, the other had difficulties recognizing the stimuli of the apraxia assessment. An eleventh patient was excluded as no informative imaging was available.

The final sample (n = 32, see **Table 1**) fulfilled the remaining inclusion criteria (i.e., right-handedness (Oldfield, 1971), age between 18 and 90 years, no psychiatric disorder) and consisted of 15 females and 17 males with a mean age of 65.9 years (*SD* = 14.7 years, range 30 to 87 years). The mean time post-stroke was 22.4 days (*SD* = 22.9 days, range 2 to 99). 30 patients suffered from an ischaemic, two from a haemorrhagic stroke. One patient did not give consent for obtaining his scans, therefore clinical imaging data (cCT: n = 7, cMRI: n = 24) was available in 31 patients only. **Figure 1** shows the lesion overlap for all apraxic patients (n =14) as well as separate lesion overlaps for the apraxic patients with full (n = 7) and with (n = 7) reduced awareness for apraxia. Despite the fact that the current 14 apraxic patients constitute a larger sample than the previous study on awareness for apraxic deficits this number is still too small for a proper statistical lesion analyses (Canzano et al., 2014).

- Please, insert Figure 1 here -

All patients gave written informed consent before participating in the study. The study was carried out in accordance with the ethical principles of the World Medical Association

(Declaration of Helsinki) and had been approved by the ethics committee of the Medical Faculty in Cologne.

Procedure

After signing the informed consent, all patients performed a set of standardized neuropsychological tests (see **Table 1**). Furthermore, a motor assessment consisting of the Action Research Arm Test (ARAT; Lyle, 1981) and the Medical Research Council (MRC) paresis scale (Medical Research Council of the United Kingdom, 1978) was administered. The ARAT is a test of hand functioning and consists of four subtests assessing grasping, holding, fine and gross motor skills of the upper limb. The MRC scale ranges from 0 ("no movement is observed") indicating hemiplegia to 5 ("muscle contracts normally against full resistance") indicating no paresis. The apraxia assessment was performed with an object use test (De Renzi, Pieczuro, & Vignolo, 1968) and the Cologne Apraxia Screening (KAS; Weiss et al., 2013). The object use tests consists of five single object tasks and two multiple object tasks in which the patients should demonstrate the use of the respective object(s). The KAS comprises assessments of imitation and pantomime deficits for bucco-facial and limb related gestures. To assess aphasia, a short version of the aphasia check list (ACL-K; Kalbe, Reinhold, & Kessler, 2002) was applied, which consists of three subtests: (i) reading aloud; (ii) auditory comprehension; and (iii) verbal fluency. Additionally, the patient's verbal communication abilities were rated by the investigator (SM). The modified Rankin Scale (mRS) was used as a general measure for the degree of disability after stroke in every patient (Rankin, 1957). The Becks Depression Inventory (BDI; Hautzinger, Bailer, Worall, & Keller, 1995) was used as an assessment of depressive symptoms.

Adopting the method from Vossel and colleagues (2012) for studying reduced awareness of neglect, the patients were asked to rate their performance in the apraxia, aphasia and motor assessment on a 5-point Likert scale with 1 ("I have insuperable difficulties and I am not able to solve the task. I am not able to correct my errors"), indicating severe difficulties, and 5 ("I do not have any difficulties in solving the task. I do not make any errors."), indicating no problems at all. To facilitate comprehension, the rating scale was accompanied by a visual rating scale with different smiley icons. Note that the patients had to indicate the specific icon that corresponded best to their subjective rating. They were not allowed to indicate a position between the icons on the visual rating scale. The investigator (SM) rated the performance of the patients for each (sub-) test on the same scale. To evaluate the degree of awareness for the respective deficit, the self-ratings of the patients were subtracted from the ratings provided by the investigator ("external rating") thereby resulting in the UnAwareness Score (UAS = Σ external rating - Σ self-rating). Here, a negative UAS (UAS < 0) indicates that the patient *over*estimated his/her performance in a given test, i.e., showed a reduced awareness of his/her deficits. Likewise, a positive UAS (UAS > 0) indicates that the patient *under*estimated his/her own performance. Finally, an UAS of zero indicates that the self- and external estimation of performance coincided. To subdivide the patients into groups with full and with reduced awareness for a given deficit (i.e. apraxia, aphasia or hemiparesis), the distribution of the respective UAS was considered: patients were classified as having a reduced awareness for a given deficit if their UAS was below the most negative UAS obtained by a patient not suffering from this deficit (for apraxia: UAS_{KAS} <-0.25, for aphasia: $UAS_{ACL\text{-}K}$ <-0.33).

To ensure the reliability of the external rating, a second rater (MK) evaluated the performance in the KAS and ACL-K subtests of those patients for whom video-taped test performances were available (n = 21). Please note that this procedure cannot be applied to the motor assessment, as it is impossible to rate the muscle strength via video-tape. Furthermore,

correlations between the external rating and the objective performance scores were calculated using Spearman's rank correlation coefficient (*rs*).

Statistical analyses

Since the presence of a deficit is essential for investigating reduced awareness, patients were grouped depending on whether or not they exhibited apraxia or aphasia. As only one of the 32 examined patients performed below cut-off in the object use test, we were not able to investigate awareness for object use deficits in the current patient sample. Therefore, the analyses focused on apraxic deficits in imitating and pantomiming gestures as measured by the KAS. Based on published cut-off scores (Kalbe et al., 2002; Weiss et al., 2013), patients were classified as apraxic if they scored less than 77 points in the KAS, and as aphasic if they scored less than 33 points in the ACL-K. As paresis was very subtle in our sample (see Table 1), we were not able to investigate reduced awareness for hemiparesis.

Since the number of subtests differed for the assessment of apraxia, aphasia and hemiparesis, the domain-specific UnAwareness Score was computed for each patient by adding up the UAS for each subtest of a given domain and dividing this sum by the number of subtests (i.e., for KAS: $UAS_{KAS} = \Sigma UAS_{KAS\text{-}subtests}/4$, for ACL-K: $UAS_{ACL\text{-}K} = \Sigma UAS_{ACL\text{-}K\text{-}subtests}/3$). Note that the verbal communication rating of the ACL-K was not included in this analysis, as this rating is *per se* performed by the therapist. These UAS were tested against zero in impaired patients only (i.e., patients with apraxia or aphasia) applying the one-sample Wilcoxon Signed Rank Test. To test for a differential effect of effector (bucco-facial vs. limb) on the awareness for apraxic deficits, we calculated separate UAS for the different effectors and compared them using the Wilcoxon Signed Rank Test (for bucco-facial gestures: $UAS_{buccofacial} = (UAS_{pantomime\text{-}bucco\text{-}facial} + UAS_{imitation\text{-}bucco\text{-}facial})/2$ and for limb gestures: $UAS_{limb} = (UAS_{pantomime\text{-}limb} + UAS_{imitation\text{-}limb})/2$). Statistical analyses were performed with the statistical software package SPSS 22 and the alpha level was set to .05 for all tests.

Results

Reliability of the external rating

The two raters showed a high interrater agreement for the apraxia and aphasia assessment (KAS: *rs* = .965, $p < .001$; ACL-K: *rs* = .925, $p < .001$) as well as for the individual KAS and ACL-K subtests (all *rs* > .727, $p < .001$). Furthermore, correlations between the external rating and the objective performance scores were highly significant for the ACL-K (*rs* = .915, $p < .001$) and the KAS (*rs* = .881, $p < .001$).

Awareness for apraxic deficits

Based on the KAS, 14 (43.8%) of the 32 LH stroke patients suffered from apraxia. The distribution of the UAS_{KAS} is displayed separately for apraxic and non-apraxic patients in **Figure 2**. As expected, the distribution of the UAS_{KAS} was centred around zero for non-apraxic patients. Half of the apraxic patients (n = 7) exhibited an UAS_{KAS} below cut-off ($UAS_{KAS} < -0.25$). Moreover, for the group of patients with apraxia (n = 14) the UAS_{KAS} was significantly different from zero (*Mdn* = -0.38, *T* = 13, *z* = -2.05, $p < .05$, effect size *r* = -0.55), reflecting an overestimation of their KAS performance at the group level. The level of awareness for apraxic deficits was neither significantly correlated with the severity of apraxia (as indexed by the KAS total score; *rs* = .330, *p* = .250) nor with time post stroke (*rs* = .413, *p* = .142). Furthermore, there was no significant difference (*p* = .762) in the UAS for limb-related (Mdn_{limb} = -0.25) and bucco-facial gestures ($Mdn_{bucco\text{-}facial}$ = -0.50). When comparing the clinical and demographic parameters between apraxic patients with full (n = 7) and with (n = 7) reduced awareness for apraxia, no significant difference was found (see **Table 1**).

- Please, insert Figure 2 here-

Awareness for aphasic deficits

Using the ACL-K, 16 (50.0%) of the 32 LH stroke patients were found to be aphasic. Note that one patient could not be assessed with the ACL-K because German was not her mother tongue compromising her performance in the reading aloud and verbal fluency tasks of the ACL-K. Six out of 16 patients exhibited a $UAS_{ACL\text{-}K}$ below cut-off ($UAS_{ACL\text{-}K}$ <-0.33, see **Figure 3**) and for the group of aphasic patients the $UAS_{ACL\text{-}K}$ was significantly different from zero (*Mdn* = -0.33, *T* = 17.5, *z* = -2.23, *p* < .05, *r* = -0.56), reflecting an overestimation of their performance in the ACL-K at the group level. Again, there was no significant correlation between the level of awareness for aphasic deficits and the severity of aphasia (as indexed by the ACL-K-score) (*rs* = .107, *p* = .693) or time post stroke (*rs* = .422, *p* =.104).

- Please, insert Figure 3 here-

Association between the awareness for apraxic and aphasic deficits

To examine the relationship between reduced awareness for apraxic and aphasic deficits, we selected those patients who suffered from both apraxia and aphasia (n = 12). As described above, these patients were classified as suffering from a reduced awareness for their apraxic deficits if they obtained an UAS_{KAS} < -0.25 and as suffering from a reduced awareness for their aphasic deficits if they obtained an $UAS_{ACL\text{-}k}$ < -0.33. Conducting a Fisher exact test, we observed no significant association between the levels of awareness for apraxic and aphasic deficits (χ^2 (1) = 1.33, *p* = .567, see **Table 2**). The Spearman Correlation with the Unawareness Scores for apraxia (UAS_{KAS}) and aphasia ($UAS_{ACL\text{-}K}$) was not significant, but revealed a trend (*rs* = .542, *p* = .069).

Discussion

The aim of the current study was to characterize the reduced awareness for apraxic (as well as aphasic) deficits in LH stroke patients. In our sample of 32 LH stroke, we found that: (i) there was a relevant number of patients showing reduced awareness for their apraxic deficits, (ii) the effector (bucco-facial vs. limb) did not differentially impact on the awareness for apraxic deficits, (iii) there was no significant association between the levels of awareness for apraxic and aphasic deficits. In what follows, we will discuss these main findings.

Based on the apraxia assessment with the Cologne Apraxia Screening (Kölner Apraxie Screening, KAS), 14 of the 32 (43.8%) LH stroke patients in our sample suffered from apraxia. These apraxic patients exhibited deficits in both pantomiming and imitation. As a group, patients with apraxia overestimated their performance in the KAS subtests, i.e., half of the apraxic patients showed a reduced awareness for their pantomime and imitation deficits. The absence of significant differences between apraxic patients with full (n = 7) and with reduced (n = 7) awareness for apraxic deficits in all assessed variables (i.e., severity of aphasia, age, time post stroke; see **Table 1**) argues against an unspecific effect of a more severe impairment in patients with reduced awareness.

Our findings in LH stroke patients suggest that apraxia is often (but not necessarily) accompanied by a reduced awareness for apraxic deficits. Therefore, our study confirms the findings by Canzano and colleagues (2014), who observed a reduced awareness for apraxic deficits in patients suffering from bucco-facial apraxia. Our results also extend these findings by showing for the first time a reduced awareness for limb apraxia as in the current sample the level of awareness for apaxic deficits did not differ between limb-related and bucco-facial gestures. Our study adds to the growing literature that reduced deficit awareness can well be caused by LH damage (e.g., Cocchini et al., 2009). To circumvent the influence of aphasic deficits, it is highly important to additionally apply a non-verbal assessment when evaluating

deficit awareness in LH patients. By the use of a visual rating scale we were able to show that reduced awareness for apraxic deficits is a frequent sequela after LH stroke.

Canzano and colleagues (2014) demonstrated the dissociation between reduced awareness for bucco-facial apraxia and gesture recognition deficits: their five apraxic patients could adequately judge gestures performed by others, but exhibited difficulties in evaluating gestures performed by themselves. This pattern of results strongly suggests that the reduced awareness of these patients suffering from bucco-facial apraxia was not merely due to a general deficit in error recognition, but a specific deficit in recognizing their own apraxic deficits (for a review on the interrelationship of apraxia, error recognition and anosognosia see Canzano et al., 2016). Since we did not include separate tests for gesture or error recognition in our study, future research is needed to investigate this issue in patients suffering from limb apraxia.

Recent research investigated the evolution of anosognosia for hemiparesis (AHP) over time in RH stroke. Vocat and colleagues (2010) showed that AHP in RH stroke patients is more frequent in the acute versus chronic phases (Vocat, Staub, Stroppini, & Vuilleumier, 2010). While AHP was present in 32% of their 58 RH stroke patients in the hyper-acute phase (at 3 days), the frequency of AHP was markedly reduced in the subacute (at 1 week: 18%) and chronic (at 6 months: 5%) phases. Furthermore, AHP in the hyper-acute phase of RH stroke was associated with lesions to the right insula and the adjacent white matter tracts while persistent AHP was linked to additional lesions in premotor and cingulate cortices, the right temporo-parietal junction and medial temporal structures (Vocat, Staub, Stroppini, & Vuilleumier, 2010). Consistent with these findings, Moro and colleagues showed in an even larger sample of RH stroke patients (n=70) that persistent AHP was associated with extensive damage to right fronto-temporal regions and the corresponding white matter tracts (e.g., superior longitudinal fasciculus; Moro et al., 2016).

Interestingly, Marcel, Tegner, and Nimmo-Smith (2004) found a dissociation with respect to the time course of AHP in LH and RH stroke patients. Whereas in RH stroke patients time post stroke was negatively associated with AHP (i.e., longer time post stroke was associated with reduced AHP as in Vocat et al., 2010), there was no relation between these variables in LH patients. Besides, the association between deficit awareness and time post stroke may depend on the specific syndrome: a study investigating anosognosia for spatial neglect in RH stroke patients did not find evidence for a correlation between time post stroke and severity of anosognosia for neglect symptoms (Vossel, Weiss, Eschenbeck, Saliger, & Karbe, 2012). In our current sample of LH stroke patients, there was no significant association between time post stroke and awareness for apraxia suggesting no time dependency of the awareness for apraxic deficits.

Further characterizing reduced awareness for apraxia, we did not find an association between apraxia (or aphasia) severity and the level of awareness for these deficits. This pattern differs from the observation in neglect patients and patients suffering from hemiparesis where the severity of unawareness is highly associated with the severity of the given syndrome (e.g., Vossel et al., 2012; Orfei et al., 2007).

Although there is a high comorbidity between apraxia and aphasia after LH stroke (Kertesz & Hooper, 1982; Timpert, Weiss, Vossel, Dovern, & Fink, 2015), there was no significant association between the levels of awareness for apraxic and aphasic deficits in the current patient sample. Unfortunately, as motor deficits in our sample were subtle, we could not investigate unawareness for hemiparesis and compare it to unawareness for apraxia. Future studies in large patient groups are warranted to further characterize the relationship between reduced awareness for apraxic and aphasic deficits and to compare reduced awareness for apraxia (a cognitive-motor deficit) to anosognosia for hemiparesis (a basic motor deficit).

One limitation of the current study is the relatively small sample size so that non-significant findings could be due to a power problem. Nevertheless, the current study is the first systematic study characterizing reduced awareness for apraxic deficits in patients suffering from bucco-facial *and* limb apraxia. Our findings shed further light on the previously underestimated importance of the left hemisphere in deficit awareness.

References

Bisiach, E., Vallar, G., Perani, D., Papagno, C., & Berti, A. (1986). Unawareness of disease following lesions of the right hemisphere: anosognosia for hemiplegia and anosognosia for hemianopia. *Neuropsychologia*, *24*(4), 471–482. http://doi.org/10.1016/0028-3932(86)90092-8

Bjørneby, E. R., & Reinvang, I. R. (1985). Acquiring and maintaining self-care skills after stroke. The predictive value of apraxia. *Scandinavian Journal of Rehabilitation Medicine*, *17*(2), 75–80.

Canzano, L., Scandola, M., Gobbetto, V., Moretto, G., D'Imperio, D., & Moro, V. (2016). The Representation of Objects in Apraxia: From Action Execution to Error Awareness. *Frontiers in Human Neuroscience*, *10*, 161–14. http://doi.org/10.3389/fnhum.2016.00039

Canzano, L., Scandola, M., Pernigo, S., Aglioti, S. M., & Moro, V. (2014). Anosognosia for apraxia: experimental evidence for defective awareness of one's own bucco-facial gestures. *Cortex*, *61*, 148–157. http://doi.org/10.1016/j.cortex.2014.05.015

Cocchini, G., Beschin, N., Cameron, A., Fotopoulou, A., & Sala, Della, S. (2009). Anosognosia for motor impairment following left brain damage. *Neuropsychology*, *23*(2), 223–230. http://doi.org/10.1037/a0014266

Cocchini, G., Gregg, N., Beschin, N., Dean, M., & Sala, Della, S. (2010). VATA-L: Visual-analogue test assessing anosognosia for language impairment. *The Clinical Neuropsychologist, 24*, 1379-1399. http://doi.org/10.1080/13854046.2010.524167

Cocchini, G., Beschin, N., Fotopoulou, A., & Sala, Della, S. (2010). Explicit and implicit anosognosia or upper limb motor impairment. *Neuropsychologia*, *48*(5), 1489–1494.

Cutting, J. (1978). Study of anosognosia. *Journal of Neurology, Neurosurgery, and Psychiatry*, *41*(6), 548–555. http://doi.org/10.2307/1171872?ref=no-x-route:2d9a60852bff9f6ac27cbfbf456f4963

De Renzi, E., Pieczuro, A., & Vignolo, L. A. (1968). Ideational apraxia: a quantitative study.

Neuropsychologia, *6*(1), 41–52. http://doi.org/10.1016/0028-3932(68)90037-7

Dovern, A., Fink, G. R., & Weiss, P. H. (2012). Diagnosis and treatment of upper limb apraxia. *Journal of Neurology*, *259*(7), 1269–1283. http://doi.org/10.1007/s00415-011-6336-y

Giaquinto, S., Buzzelli, S., Francesco, L., Lottarini, A., Montenero, P., Tonin, P., & Nolfe, G. (1999). On the prognosis of outcome after stroke. *Acta Neurologica Scandinavica*, *100*(3), 202–208. http://doi.org/10.1111/j.1600-0404.1999.tb00740.x

Hautzinger, M., Bailer, M., Worall, H., & Keller, F. (1995). Becks-Depression-Inventory (BDI) (2nd ed.). Verlag Hans Huber, Hogrefe AG, Bern.

Kalbe, E., Reinhold, N., & Kessler, J. (2002). Kurze Aphasie-Check-Liste (ACL-K). UCB-Pharma GmbH Kerpen.

Kertesz, A., & Benson, D. F. (1970). Neologistic Jargon: A clinicopathological study. *Cortex*, *6*(4), 362–386. http://doi.org/10.1016/S0010-9452(70)80002-8

Kertesz, A., & Hooper, P. (1982). Praxis and language: the extent and variety of apraxia in aphasia. *Neuropsychologia*, *20*(3), 275–286.

Langer, K. G., & Levine, D. N. (2014). Babinski, J. (1914). Contribution to the study of the mental disorders in hemiplegia of organic cerebral origin (anosognosia). Translated by K.G. Langer & D.N. Levine. *Cortex*, *61*(C), 5–8. http://doi.org/10.1016/j.cortex.2014.04.019

Lyle, R. C. (1981). A performance test for assessment of upper limb function in physical rehabilitation treatment and research. *International Journal of Rehabilitation Research*, *4*(4), 483–492.

Marcel, A. J., Tegner, R., & Nimmo-Smith, I. (2004). Anosognosia for plegia: Specificity, extension, partiality and disunity of bodily unawareness. *Cortex*, *40*, 19–40. http://doi.org/10.1016/S0010-9452(08)70919-5.

Medical Research Council of the United Kingdom (1978). Aids to examination of the

peripheral nervous system: memorandum No 45. Palo Alto, CA: Pedragon House.

Moro, V., Pernigo, S., Tsakiris, M., Avesani, R., Edelstyn, N. M. J., Jenkinson, P. M., & Fotopoulou, A. (2016). Motor Versus Body Awareness: Voxel-based Lesion Analysis in Anosognosia for Hemiplegia and Somatoparaphrenia Following Right Hemisphere Stroke. *Cortex, 62-77.* http://doi.org/10.1016/j.cortex.2016.07.001

Moro, V., Pernigo, S., Zapparoli, P., Cordioli, Z., & Aglioti, S. M. (2011). Phenomenology and neural correlates of implicit and emergent motor awareness in patients with anosognosia for hemiplegia. *Behavioural Brain Research*, *225*(1), 259–269. http://doi.org/10.1016/j.bbr.2011.07.010

Nathanson, M., Bergman, P. S., & Gordon, G. G. (1952). Denial of illness: its occurrence in one hundred consecutive cases of hemiplegia. *A.M.a. Archives of Neurology & Psychiatry*, *68*(3), 380–387. http://doi.org/10.1001/archneurpsyc.1952.02320210090010

Nurmi, M. E., & Jehkonen, M. (2014). Assessing anosognosias after stroke: A review of the methods used and developed over the past 35 years. *Cortex*, *61*(C), 43–63. http://doi.org/10.1016/j.cortex.2014.04.008

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia*, *9*(1), 97–113. http://doi.org/10.1016/0028-3932(71)90067-4

Orfei, M. D., Robinson, R. G., Prigatano, G. P., Starkstein, S., Rusch, N., Bria, P., et al. (2007). Anosognosia for hemiplegia after stroke is a multifaceted phenomenon: a systematic review of the literature. *Brain*, *130*(12), 1–16. http://doi.org/10.1093/brain/awm106

Raade, A. S., Rothi, L. J., & Heilman, K. M. (1991). The relationship between buccofacial and limb apraxia. *Brain and Cognition*, *16*(2), 130–146.

Rankin, J. (1957). Cerebral vascular accidents in patients over the age of 60. II. Prognosis. *Scottish Medical Journal*, *2*(5), 200–215.

Stone, S. P., Halligan, P. W., & Greenwood, R. J. (1993). The incidence of neglect

phenomena and related disorders in patients with an acute right or left hemisphere stroke. *Age and Ageing*, *22*(1), 46–52. http://doi.org/10.1093/ageing/22.1.46

Sundet, K., Finset, A., & Reinvang, I. (1988). Neuropsychological predictors in stroke rehabilitation. *Journal of Clinical and Experimental Neuropsychology*, *10*(4), 363–379. http://doi.org/10.1080/01688638808408245

Timpert, D. C., Weiss, P. H., Vossel, S., Dovern, A., & Fink, G. R. (2015). Apraxia and spatial inattention dissociate in left hemisphere stroke. *Cortex*, *71*(C), 349–358. http://doi.org/10.1016/j.cortex.2015.07.023

Vocat, R., Staub, F., Stroppini, T., & Vuilleumier, P. (2010). Anosognosia for hemiplegia: a clinical-anatomical prospective study. *Brain*, *133*(12), 1–20. http://doi.org/10.1093/brain/awq297

Vossel, S., Weiss, P. H., Eschenbeck, P., Saliger, J., & Karbe, H. (2012). The neural basis of anosognosia for spatial neglect after stroke. *Stroke*, *43*(7), 1954–1956. http://doi.org/10.1161/STROKEAHA.112.657288/-/DC1

Weiss, P. H., Kalbe, E., Kessler, J., Fink, G. R., Binder, E., Hesse, M. D., & Scherer, A. (2013). Kölner Apraxie Screening. Hogrefe: Göttingen.

Table 1. ***Patients' Characteristics***

	Patients without apraxia (n = 18)	***Patients with apraxia (n = 14)***	***Patients with awareness for apraxia (n = 7)***	***Patients with reduced awareness for apraxia (n = 7)***
KAS total	80 (77-80)	67 (41-76) **	67 (41-76)	66 (50-72)
KAS pantomime bucco-facial	20 (18-20)	15.5 (13-20) **	15 (13-20)	18 (13-20)
KAS pantomime limb	20 (18-20)	16 (8-20) **	18 (8-20)	16 (9-20)
KAS imitation bucco-facial	20 (18-20)	17 (4-20) *	20 (4-20)	16 (12-20)
KAS imitation limb	20 (18-20)	18 (12-20) *	20 (12-20)	18 (14-20)
Tool Use Test	32 (30-32)	31 (29-32) *	31 (30-32)	31 (29-32)
ACL-K total	36 (29-38)	27.5 (14-37) **	25.75 (14-30.5)	29.5 (20-37)
MRC paresis scale (right hand)	5 (0-5)	4.25 (0-5)	4,5 (0-5)	4 (0-5)
ARAT (right hand)	57 (0-57)	56.5 (0-57)	57 (0-57)	56 (0-57)
modified Rankin Scale (mRS)	1 (0-4)	3.5 (0-4)	4 (2-4)	3 (0-4)
LQ	94.7 (50-100)	90 (64.7-100)	100 (78.9-100)	90 (64.7-100)
Age (years)	59.5 (30-87)	78 (49-87) *	78 (49-85)	78 (51-87)
Time post stroke (days)	18.5 (2-68)	7 (2-99)	29 (3-99)	6 (2-29)
BDI	4 (0-13)	5 (1-16)	9 (3-16)	3 (1-10)

Note. The median and the range are provided. Using the non-parametric Mann-Whitney U Test, the group of apraxic patients was compared to the group of non-apraxic patients (significant group differences between apraxic and non-apraxic patients: * $p < .05$, ** $p < .001$). There were no significant differences between apraxic patients with full and with reduced awareness for apraxia.

KAS = Cologne Apraxia Screening, ACL-K = Aphasia Check List- short version, MRC = Medical Research Council, ARAT = Action Research Arm Test, LQ = Laterality Quotient as assessed by the Edinburgh Handedness Inventory (Oldfield, 1971), BDI = Beck's Depression Inventory.

Table 2. ***Crosstable for the association of reduced awareness for apraxic and aphasic deficits in patients suffering from both apraxia and aphasia.***

		Reduced awareness for apraxic deficits		
		yes	*no*	***total***
Reduced awareness for aphasic deficits	*yes*	4	2	***6***
	no	2	4	***6***
	total	***6***	***6***	***12***

Note. Fisher exact test: χ^2 (1) = 1.33, p = .567

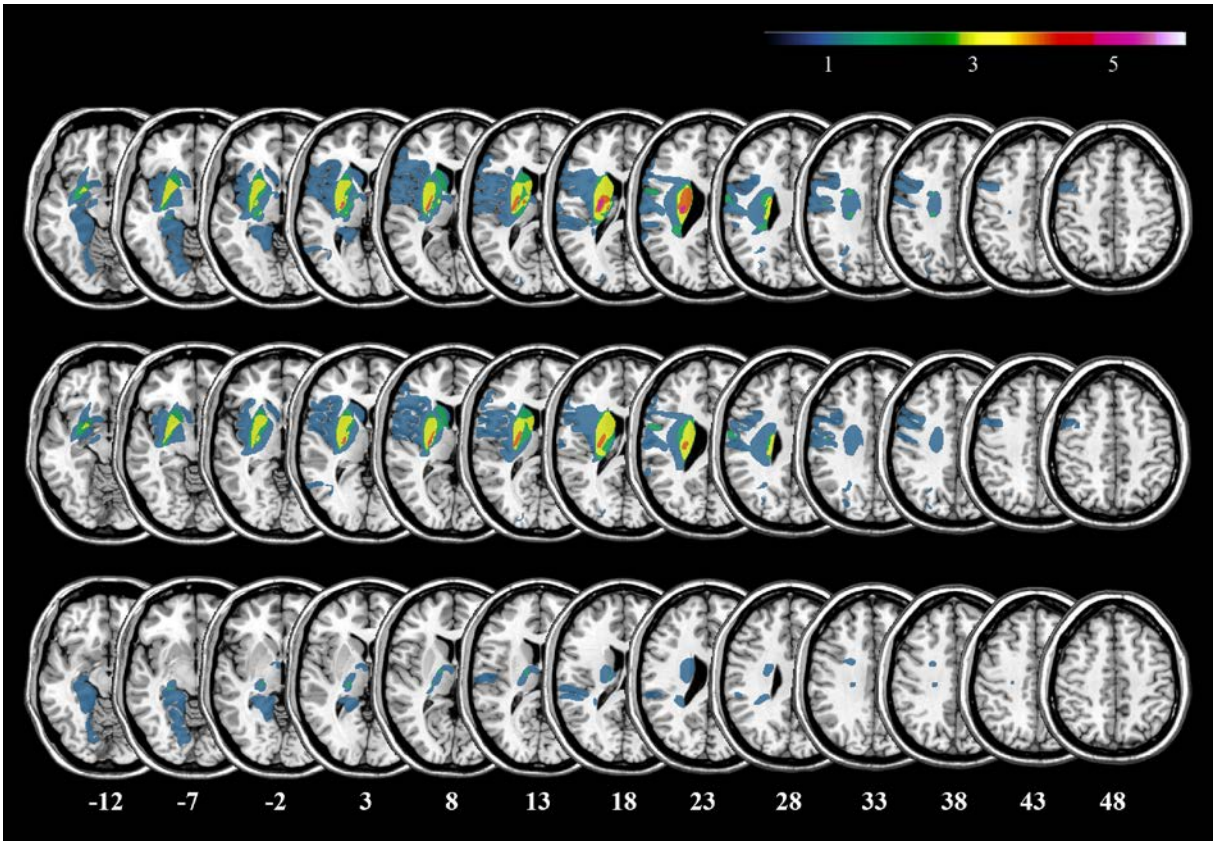

Figure 1. Lesion overlap of all apraxic patients (upper panel, n = 14), of apraxic patients with full (central panel; n = 7) and with reduced awareness (lower panel; n = 7). Colours represent an increasing number of overlapping lesions (from cold to warm colours).

Slices with the MNI-z-coordinates from -12 to 48 are shown.

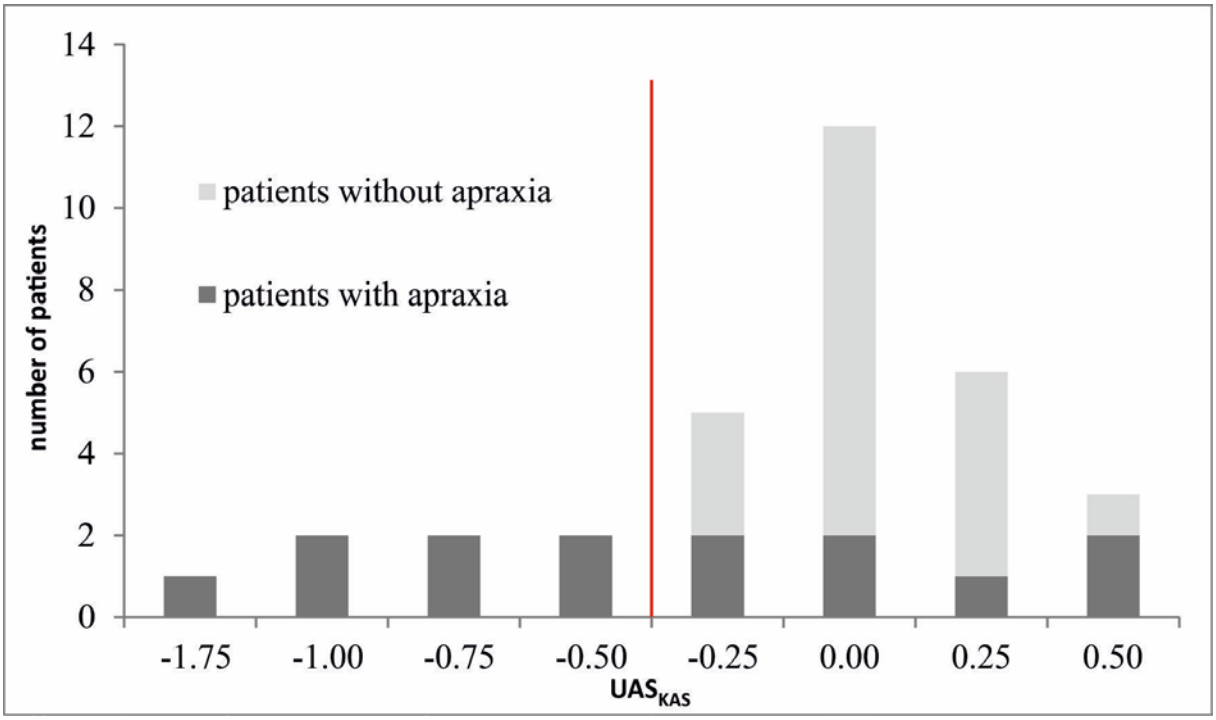

Figure 2. Distribution of the Unawareness Score for apraxia (UAS_{KAS}) displayed separately for apraxic (n =14, dark grey) and non-apraxic (n =18, light grey) patients. Negative scores reflect higher self- than external ratings, i.e. an overestimation of her/his KAS performance by the patient. The red line separates apraxic patients with reduced awareness (UAS_{KAS} < -0.25) from apraxic patients with full awareness (UAS_{KAS} >= -0.25).

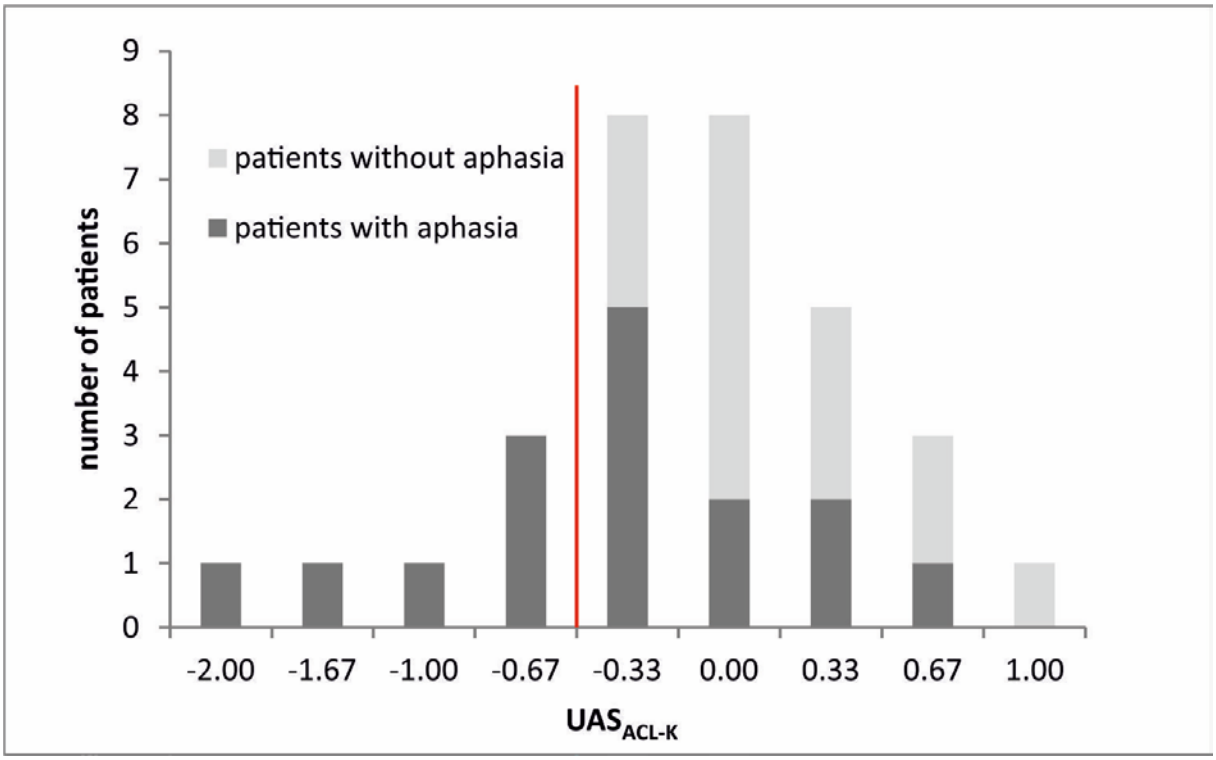

Figure 3. Distribution of the Unawareness Score for aphasia ($UAS_{ACL\text{-}K}$) displayed separately for aphasic (n =16, dark grey) and non-aphasic (n =15, light grey) patients. Negative scores reflect higher self- than external ratings, i.e. an overestimation of her/his ACL-K performance by the patient. The red line separates aphasic patients with reduced awareness ($UAS_{ACL\text{-}K} < -0.33$) from aphasic patients with full awareness ($UAS_{ACL\text{-}K} >= -0.33$).