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**Association of Cognitive-linguistic Deficits to Diffusion Tensor
Imaging Parameters in Moderate to Severe Traumatic Diffuse Axonal
Injury**

Marjaana Raukola-Lindblom^{a*}, Timo Kurki^{b,c}, Linda Ljungqvist^d, Marja
Laasonen^e, Heikki Hämäläinen^a, and Olli Tenovuo^{f,g}

*^aDepartment of Psychology and Speech-Language Pathology, University of Turku,
Finland; ^bDepartment of Radiology, University of Turku, Finland; ^cTerveystalo Medical
Center, Turku, Finland; ^dCity of Turku, Welfare division, Psychosocial services,
Finland; ^eLogopedics, School of Humanities, University of Eastern Finland, Finland;
^fDepartment of Clinical Neurosciences, University of Turku, Finland; ^gTurku Brain
Injury Center, Neurocenter, Turku University Hospital, Finland*

*corresponding author: Marjaana Raukola-Lindblom, Department of Psychology and
Speech-Language Pathology, Faculty of Social Sciences, 20114, University of Turku,
Finland. Tel.: +358 50 344 4343; E-mail:
marjaana.raukola-lindblom@utu.fi

Biographical notes:

Marjaana Raukola-Lindblom is a Specialized Speech-Language Pathologist, University
Lecturer, and Doctoral Candidate at the University of Turku, Finland

Timo Kurki is a Neuroradiologist and Associate Professor at the University of Turku, Finland

Linda Ljungqvist is a Psychologist specializing in Clinical Neuropsychology at the University
of Helsinki, Finland

Marja Laasonen is a Clinical Neuropsychologist and a Professor of Logopedics at the
University of Eastern Finland

Heikki Hämäläinen is an Emeritus Professor of Psychology at the University of Turku, Finland

Olli Tenovuo is a Professor of Neurotraumatology at the University of Turku and Head of the
Turku Brain

Association of Cognitive-linguistic Deficits to Diffusion Tensor

Imaging Parameters in Moderate to Severe Traumatic Diffuse Axonal Injury

Cognitive-linguistic functions are an essential part of adequate communication competence. Cognitive-linguistic deficits are common after traumatic diffuse axonal injury (DAI). We aimed to examine the integrity of perisylvian white matter tracts known to be associated with linguistic functions in individuals with DAI and their eventual association with poor cognitive-linguistic outcomes. Diffusion tensor imaging (DTI) results of 44 adults with moderate-to-severe DAI were compared with those of 67 controls. Fractional anisotropy (FA) values of the superior longitudinal fasciculus (SLF), arcuate fasciculus (AF), SLF with frontal connections to the lower parietal cortex, and AF with temporal connections to the lower parietal cortex were measured using tractography. The associations between white matter integrity FA values and cognitive-linguistic deficits were studied in the DAI group. Cognitive-linguistic deficits were determined based on our earlier study using the novel KAT test. No previous studies have examined the associations between white matter integrity and cognitive-linguistic deficits determined using the KAT test.

Patients with DAI showed lower FA values in all left-side tracts than the controls. Unexpectedly, the poor cognitive-linguistic outcome in the language comprehension and production domains was associated with high FA values of several tracts. After excluding five cases with the poorest cognitive-linguistic performance, but with the highest values in the DTI variables, no significant associations with DTI metrics were found.

The association between white matter integrity and cognitive-linguistic functioning is complex in patients with DAI of traumatic origin, probably reflecting the heterogeneity of TBI.

Keywords: traumatic brain injury; diffuse axonal injury, cognitive-linguistic; diffuse tensor imaging, white matter tract

Introduction

Traumatic brain injury (TBI) is a leading cause of disability in young and working-age adults worldwide (Popescu et al., 2015). In TBI, acceleration-deceleration and rotational forces often lead to stretching, shearing, and deformation of the brain tissue, resulting in widespread diffuse axonal injury (DAI) (Eijck et al., 2018; Siedler et al., 2014). DAI is known to cause multi-layered persistent cognitive communication deficits (Avramović et al., 2017; MacDonald, 2017; Raukola-Lindblom et al., 2021), which may lead to difficulties in returning to work (Rietdijk et al., 2013), social interactions, and feelings of isolation and loneliness (Ponsford et al., 2014).

Language is one of the most fundamental elements of cognitive competence in human interaction. Language functions are complex, dynamic, and dependent on other cognitive functions such as working memory, executive function, and processing speed (Avramović et al., 2017). Today, a common understanding is that language functions are supported by distributed, large-scale, highly interconnected cortical and subcortical dynamic and plastic networks (Chang et al., 2015; Dick & Tremblay, 2012; Friederici, 2011; Fujii et al., 2016), reflecting their connection to multiple cognitive functions (Avramović et al., 2017; Ewing-Cobbs & Barnes, 2002; Yang et al., 2010). Several axonal structures have been identified to play a role in cognitive-linguistic functions. There is consensus on a model for the dorsal and ventral streams of information flow between language-related areas, including specific tracts, that is, the dominant hemisphere arcuate fasciculus (AF) and superior longitudinal fasciculus (SLF) and their frontal and temporal connections to the lower parietal cortex (Axer et al., 2013; Barbeau et al., 2020; Bernard et al., 2019; Fujii et al., 2016; Yagmurlu et al., 2016), which are associated with phonological processing, high-level syntactic information processing,

and lexical and semantic processing (Smits et al., 2014; Yagmurlu et al., 2016). In clinical practice, predicting cognitive-linguistic outcomes in patients with DAI would greatly benefit their prognostic knowledge (Eijck et al., 2018).

Cognitive-linguistic deficits in DAI

DAI is often associated with poor cognitive outcomes that affect communication competence, such as processing speed, working memory, and executive function (Avramović et al., 2017; Ewing-Cobbs & Barnes, 2002; Scheid et al., 2006; Strain et al., 2017; Tae et al., 2018; Yang et al., 2010). DAI is also associated with long-term perceived fatigue, affecting individuals' communication competence and, more specifically, cognitive-linguistic functions in everyday life (Raukola-Lindblom et al., 2021). Cognitive-linguistic deficits typical of DAI are related to difficulties in language production and comprehension, reading, writing, conversation, and social participation (MacDonald, 2017; Raukola-Lindblom et al., 2021; Togher et al., 2014). [Cognitive-linguistic deficits are often a combination of problems in different cognitive components, such as memory, executive functions, and linguistic processes \(MacDonald, 2017\).](#) In our previous study (Raukola-Lindblom et al., 2021), participants with moderate to severe DAI exhibited long-term deficits in multiple cognitive-linguistic processing domains, as confirmed in other studies (Gauthier et al., 2018; LeBlanc et al., 2006, 2020; Lee & Kim, 2016). We used the selected subtests of the Finnish KAT test and created composite variables to profile the types of deficits. Participants with DAI differed significantly from healthy controls in linguistic working memory, language production, and language comprehension domains. We found no significant differences between the groups in the reading and writing domains based on the KAT test (Raukola-Lindblom et al., 2021).

Association of cognitive-linguistic deficits with DTI-parameters in TBI

Diffusion tensor imaging (DTI) can identify diffuse and focal abnormalities in the structural connections between different brain regions (Eijck et al., 2018; Friederici, 2011; Inglese et al., 2005; Mohammadian et al., 2016; Tae et al., 2018). It is based on the ability to determine the orientation and diffusion characteristics of white matter by measuring the motility of water molecules in the tissues (Tae et al., 2018). DAI is associated with decreased diffusion anisotropy (Arfanakis et al., 2002). Fractional anisotropy (FA) parameters have been shown to reflect the degree of white matter pathway damage, as well as mean diffusivity (MD) and white matter volume (Bourke et al., 2021; Mohammadian et al., 2016). DTI is a useful method for detecting white matter lesions in areas commonly damaged by TBI, such as the anterior corona radiata, uncinate fasciculus, superior longitudinal fasciculus, and corpus callosum (Tae et al., 2018). However, DTI has inherent limitations, and there are inconsistencies in the results of FA and MD measurements in TBI (Mohammadian et al., 2016).

There is evidence of decreased white matter FA values in individuals with acute to chronic stages of DAI and mild to severe injuries (Eijck et al., 2018; Mohammadian et al., 2016; Wallace et al., 2020). Studies examining the association between DTI parameters and cognitive-linguistic outcomes have had varying findings (Croall et al., 2014; Koshiyama et al., 2020; Veeramuthu et al., 2015; Wallace et al., 2020; Wang et al., 2021). Veeramuthu et al. (2015) studied DTI parameters in traumatic axonal injury and their correlation with cognitive impairment, including the language domain. There were negative associations between the SLF FA values and performance in the language domain (which included naming and auditory comprehension tasks) in the acute and chronic phases of injury, indicating that poor linguistic performance was associated

with better SLF integrity. Interestingly, in their longitudinal study, 63.3% of patients remained impaired within the domain of language function, and some even worsened over time. Similar unexpected negative associations have been found between AF and linguistic performance including verbal fluency and picture naming (Wang et al., 2021).

In contrast, Strain and colleagues (Strain et al., 2017) found positive correlations; poor naming scores were associated with weaker whole-brain FA values. In their study, the integrity of SLF was not associated with naming scores. Positive correlations were also found in a study that examined the association between poor verbal comprehension and weaker SLF integrity (Koshiyama et al., 2020). Wallace et al. (2020) did not find significant correlations between DTI findings and cognitive outcomes, even though moderate to severe TBI was associated with large white matter alterations and poorer cognitive performance. The cognitive domains did not include separate linguistic variables in their study, but had some tasks with linguistic factors.

There is growing evidence of changes in white matter integrity and cognitive-linguistic performance after DAI. Recent studies examining the association between DTI parameters and cognitive-linguistic deficits have yielded varying results. In studies using tractography, the SLF and AF are generally analyzed, but tracts to the lower parietal lobe cortex are seldom included. No previous studies have examined the associations between white matter integrity and cognitive-linguistic deficits determined using the KAT test. This study aimed to investigate the integrity of the SLF, AF, and the tracts connecting these to the lower parietal cortex in individuals with moderate to severe DAI and whether the integrity of these tracts was associated with cognitive-linguistic deficits. The expectation was that individuals with DAI had lower integrity in DTI parameters than healthy controls. We hypothesized that lower FA values in these

tracts would correlate with poorer cognitive-linguistic outcomes. However, we made this hypothesis with caution since the results of earlier studies have varied.

Methods

Subjects and procedures

Subjects with DAI of traumatic origin (referred to as the DAI group) were recruited through the outpatient clinic of patients with traumatic brain injury, Turku University Hospital, Finland, based on their medical records. [We recruited 102 potentially eligible participants with DAI, and 53 volunteered. Five were excluded because of exclusion criteria found during the first contact, and four participants were excluded because of missing data \(missed appointments\).](#) The subjects in the healthy control group were a convenience sample composed of acquaintances of the research group and assistants. [All of the 67 recruited healthy controls participated in the study.](#) The demographic variables of the control group followed those of the DAI group. [Those with a history of learning or language disability, psychiatric disorders, drug or alcohol abuse, severe visual or hearing impairments, or neurological conditions were excluded.](#)

Attendance at the assessments was voluntary, and the participants did not receive any financial compensation. Participants completed the study assessments on different dates within one month in two locations: the University of Turku, Department of Psychology and Speech-language Pathology, where the cognitive-linguistic evaluations were conducted, and the Terveystalo Medical Center, where the MRIs (with DTI) were performed.”.

The participants were native Finnish-speaking, right-handed, working-age adults aged 19–[52-50](#) years. Those who had a history of learning or language disability, psychiatric disorders, drug or alcohol abuse, severe visual or hearing impairments, or neurological conditions other than DAI were excluded. The participants with DAI had

to show moderate to severe DAI based on the lowest Glasgow Coma Score and/or duration of posttraumatic amnesia (O'Neil et al., 2013) and no contusions or intracranial bleeding (excluding microhemorrhages) on brain MRI. A neurologist (OT) evaluated the inclusion and exclusion criteria before asking for consent. For those willing to participate, a questionnaire was used to assess the study requirements before inclusion in the study. The Ethics Committee of the Hospital District of Southwest Finland granted ethical clearance (ETMK 86/1801/2016) for this study and the hospital conferred a data collection permit.

Measures

MRI and analysis

MRI was performed at 3T (Intera, Philips Medical Systems, Best, Netherlands) using a sensitivity encoding 8-channel transmit-receive head coil. Axial DTI images were obtained: TR/TE 3347.6 ms/83.8 ms, 60 slices with 2.0-mm thickness, SENSE factor 3, FOV 224 mm, flip angle 90 degrees, imaging time 8 min 35 sec, b value 800 sec/mm², 32 different gradient encoding directions were used, and the images had a 2.00×1.75×1.75-mm voxel size. Additionally, transverse T2-weighted turbo spin-echo, susceptibility-weighted, coronal fluid-attenuated inversion recovery (FLAIR), and sagittal 3DT1 turbo field echo images were obtained.

DTI images were obtained according to the line between the lower border of the genu and splenium of the corpus callosum (CC). Post-processing with a diffusion registration tool was performed to remove distortions and misalignments due to shear and eddy currents, and head motion.

Deterministic DTI tractography (DDT) (FiberTrak package, Philips) was performed using previously reported region-of-interest (ROI) positions (Brandstack et

al., 2016). Tract volumes were measured with an FA threshold of 0.30 and a direction threshold of $<40^\circ$. Furthermore, central FA values (FAC) were measured within a volume of 3 cm^3 in the AF and 6 cm^3 in the SLF (Kurki et al., 2014). Furthermore, the fibers from the frontal and temporal lobes to the lower parietal lobe cortex (supramarginal and angular gyrus) were measured using an additional ROI. The fibers between the frontal lobe and lower parietal lobe were combined with the SLF (SLF+front-gesch), and the fibers between the temporal lobe and lower parietal lobe were combined with the AF (AF+tempor-gesch).

Cognitive-linguistic measures

A battery of subtests used to test cognitive-linguistic functions was administered to patients with DAI. [Since cognitive-linguistic deficits are often a combination of problems in different cognitive components, such as memory, executive functions, and linguistic processes, we used a measure that captures the cognitive-linguistic functions comprehensively.](#) The subtests [for our study](#) were selected from the Finnish KAT-test (Manninen et al., 2015) and formed into four composite variables: Linguistic working memory, language comprehension, language production, and reading and writing. We reported this procedure and outcome in detail in our earlier research article (Raukola-Lindblom et al., 2021), where we compared the cognitive-linguistic outcomes between the DAI and healthy control groups. For this study, we selected the results of the performance of three composite variables that differed significantly between participants with DAI and healthy controls. These were linguistic working memory, language comprehension, and language production. The subtests of the three selected domains are presented in Table 1.

Since the total scores of the subtests differed in these composite variables, standardized values (z-scores) were calculated for all these scores. Calculations were performed in the DAI group. The composite variables were the means of these z-scores. Larger positive values indicated better performance without transformation.

Statistical analysis

Data analyses were performed using IBM SPSS Statistics version 26.0 (IBM Corp., Armonk, NY, USA, 2019). Statistical significance was set at $p < 0.05$. The plausibility of the data was judged by means and standard deviations, and reasonable maximum and minimum values. Outliers were detected by observing the histograms, boxplots, and scores. Outliers emerged as univariate extreme values. Because the participants belonged to the target population and these values seemed realistic, we chose not to remove them. The normality of the data distribution was assessed using the Shapiro-Wilk test. The distribution of values was highly skewed in one of the cognitive-linguistic composition variables, language comprehension. Nonparametric tests were also used to verify the results of the parametric tests on nonnormally distributed data.

Two-sample *t*-tests were conducted to determine whether there was a statistically significant difference between the DAI and healthy control groups in terms of DTI scores. In addition, a non-parametric Mann-Whitney U test was conducted to verify the results of the parametric tests. The results were similar and we chose to present only the results of the parametric analyses.

Pearson correlations were conducted to evaluate the association between DTI findings and cognitive-linguistic outcomes in the DAI group. Spearman correlations were conducted to verify the parametric test results. The results were similar, and only the results of the parametric analyses are presented. The correlations were also

examined using scatter plots and conducted again when five cases with a value of -1 or less (means of standardized composite scores) in cognitive-linguistic measures were removed.

Results

Study population

The DAI group consisted of 44 participants (14 males and 30 females) aged 19-50 ($M = 35$, $SD = 9.4$). [The inclusion and exclusion criteria of the participants are presented in the previous subjects and procedures -section.](#) The primary injury type for all participants was DAI due to TBI. Injury severity varied from moderate ($N = 19$) to severe ($N = 25$) based on the lowest Glasgow Coma Score and/or duration of post-traumatic amnesia. The participants were in the chronic phase (> 12 months post-onset), and their post-injury time varied from 1 year to 27 years (Mean = 7.2 years, $SD 7.5$).

The control group for comparison of DTI scores consisted of 67 healthy participants (30 men and 37 women), aged 17-52 ($M = 36$, $SD = 10$) years. There were no differences in sex ($\chi^2(1) = 1.86$, $p = 0.17$) or age ($t(97) = -0.27$, $p = 0.79$) between the two groups. [The exclusion criteria were identical in both groups.](#)

DTI metrics in DAI patients compared to healthy controls

Individuals with DAI showed statistically significantly lower mean FA values on the left SLF and AF, as well as on measurements including the left frontal and temporal connections of the lower parietal cortex, compared to healthy controls. There were no significant differences in the right hemisphere tracts between the DAI group and healthy controls. The results of the group comparisons are shown in Table 2.

Correlations between cognitive-linguistic deficits and diffusion metrics in DAI group

Of the cognitive-linguistic outcomes, two of the three domains correlated significantly with diffusion metrics. All significant correlations were negative, indicating that poor cognitive-linguistic outcomes were associated with better integrity of the correlated tracts. The language comprehension domain correlated negatively with the FA values of the right and left SLF as well as with measurements including the right frontal and temporal connections to the lower parietal cortex. The language production domain was negatively correlated with the FA values of the right AF, including temporal connections to the lower parietal cortex. There were no significant correlations between the linguistic working memory domain and any of the measured tracts, nor were there significant correlations between any of the cognitive-linguistic domains and the left AF, with or without temporal connections to the lower parietal cortex. The measured correlations between the cognitive-linguistic variables and FA values are presented in Table 3.

When the correlations were examined with scatter plots, we localized five cases that formed a subgroup: they had the lowest values, -1 or less (means of standardized composite scores), in language comprehension and production; however, they were among the highest values in the DTI variables. After removing these five cases, none of the correlations were statistically significant.

Discussion

This study examined the integrity of the white matter tracts in individuals with moderate to severe DAI and whether microstructural measures (FA values) were associated with long-term cognitive-linguistic deficits. All measurements were completed within one month in the chronic state of DAI. Our results confirmed that individuals with DAI had abnormalities in diffusion metrics in the left hemisphere compared to healthy age- and sex-matched controls. However, we did not find significant associations between any of

the measured tracts in the left hemisphere and performance in the three cognitive-linguistic domains (linguistic working memory, language comprehension, and language production) defined in our previous study (Raukola-Lindblom et al., 2021). In contrast, we observed negative associations between the FA values of the measured tracts in the right hemisphere and performance in language comprehension and production domains. When the five cases with extremely poor performance in the cognitive-linguistic domains but still high values in the DTI variables were excluded, no significant associations between diffusion metrics and cognitive-linguistic deficits were found.

Our results are similar to those of many previous studies that have observed decreased diffusion metrics in individuals with DAI compared to healthy controls (Arfanakis et al., 2002; Eijck et al., 2018; Mohammadian et al., 2016; Wallace et al., 2020), which supports our expectations. According to our findings, participants with DAI had significantly lower mean FA values in the left SLF and AF, as well as in measurements including connections to the lower parietal cortex. These white matter connections on the left side are essential for proper cognitive-linguistic functioning, such as phonological processing needed for speech production, and high-level syntactic and semantic processing required for language comprehension and production (Axer et al., 2013; Fujii et al., 2016; Smits et al., 2014). In contrast, no significant differences were found in the tracts measured in the right hemisphere between the groups. Our findings confirmed that this particular chronic-stage DAI group had weaker integrity in the white matter tracts of the left hemisphere and, according to our previous findings, poorer performance in cognitive-linguistic domains (Raukola-Lindblom et al., 2021). The relationship between cognitive outcome and white matter tract integrity has varied in previous studies (Koshiyama et al., 2020; Veeramuthu et al., 2015; Wallace et al., 2020; Wang et al., 2021). The variability in the terminology used when describing

fronto-parieto-temporal tracts and their connections makes the comparison of study results challenging (Ellis & Larsen-Freeman, 2009).

Contrary to our hypothesis, our results showed that the associations between diffusion metrics and cognitive-linguistic deficits were either negative or insignificant. Although cognitive-linguistic performance in linguistic working memory, language comprehension and production, and the integrity of white matter tracts in the left hemisphere were significantly poorer in the DAI group than in the controls, no positive associations were found. Instead, negative associations, meaning worse performance associated with higher FA, were observed between language comprehension and production deficits, and white matter tracts in the *right* hemisphere. The results of our study are similar to those of previous studies where either no associations were found or the correlations were negative between diffusion metrics and language functions (Koshiyama et al., 2020; Veeramuthu et al., 2015; Wallace et al., 2020; Wang et al., 2021).

The findings of lower FA values associated with a better cognitive-linguistic outcome are challenging to explain because of their apparent contradiction to the group-wise findings. In previous studies on the chronic phase of DAI, negative correlations have been suggested to stem from glial scarring, a relative increase in the proportion of axons with smaller diameters, and network organization (Croall et al., 2014; Veeramuthu et al., 2015). When we studied the correlation scatter plot images in the DAI group, we noted several cases with poorer performance in the language comprehension and production domains but were among the highest values in the DTI. In the linguistic working memory domain, these individual cases did not have extremely low performance scores compared to the rest of the group. After excluding five cases with the poorest performance in language comprehension and production domains, but

with the highest values in DTI variables, no significant correlations were found in the rest of the group. There may be numerous explanations for the negative correlations found before excluding these five cases, as has been speculated in similar findings in earlier studies. Since the negative association concerned only these five cases and the tracts in the right hemisphere, we speculate that there might be some notable individual neural reorganization demonstrating the increase in right hemisphere involvement as a compensatory mechanism (Croall et al., 2014; Voets et al., 2006). Also, similar suggestions for these kinds of results have been given in other patient groups. For example, Mole et al. (2016) found increased FA values and increased axial diffusivity in the motor pathways of patients with Parkinson's disease, suggesting adaptive neuroplasticity or selective neurodegeneration. Also, our findings could be related to these phenomena. Nevertheless, our results on the relationship between cognitive-linguistic outcomes and diffusion metrics support the heterogeneity of individuals with DAI as well as the complexity of linguistic functions. [Cognitive-linguistic deficits are often a combination of problems in different cognitive components, such as memory, executive functions, and linguistic processes \(MacDonald, 2017\), which also may influence the heterogeneity of the results.](#) In future research, it could be beneficial to study subgroups with extremely poor cognitive-linguistic performance but high values in DTI metrics in more detail.

Our study has some limitations. Our earlier study evaluated the cognitive-linguistic outcome using the KAT test that was not initially designed for this particular patient group; therefore, some cognitive-linguistic deficits specific to traumatic DAI may have remained undetected. It is also available only in Finnish; therefore, its results are not entirely comparable with those of other studies. However, in our earlier study,

we confirmed that this method is a valuable tool for detecting cognitive-linguistic deficits due to DAI. We also studied the defined domains in detail.

Our study population was carefully selected to be as homogeneous as possible. However, there was variation in the background variables, which may have affected the results. We could not consider the potential effects of the participants' years of education since we did not have this information from the healthy control group. There were also some differences in injury severity in the DAI group. Earlier research suggests that the severity of the injury from moderate to severe or the time post-injury from post-acute to chronic does not significantly influence the results of diffusion metrics (Kinnunen et al., 2011; Veeramuthu et al., 2015). Still, the properties of our patient characteristics may explain the results, and this constant challenge in TBI research may explain the variable results in different studies.

We used only FA values in the analysis in this study for simplicity. However, analysis of other DTI parameters, white matter and cortical volumes could have additional value in explaining the findings. In addition to correlations, other statistical analyses may also be considered for evaluating the associations between subcortical structures and cognitive-linguistic deficits in more detail.

Conclusions

Our study provides new insights into understanding the heterogeneity of the DAI population, both in cognitive-linguistic performance and in structural features of the white matter tracts. The differences in diffusion metrics between participants with DAI and healthy controls in our study demonstrated alterations in the integrity of connectomes between specific subcortical structures. Although we found evidence that the same group with DAI had more deficits in multiple cognitive-linguistic functions and reduced integrity of the tracts in the left hemisphere, the prognostic value of the

latter is not clear due to the lack of significant associations. Our findings underscore the heterogeneous nature of the DAI and its cognitive consequences. For clinical purposes, it is necessary to conduct a comprehensive evaluation using multiple available methods to obtain a holistic and robust view of functional abilities and underlying neural mechanisms in individuals with DAI.

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Declaration of interest

The authors report no conflicts of interest.

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Table 1. Selected cognitive-linguistic composite variables and the subtests of the KAT test with task descriptions

Composite variable	Subtest	Task description (auditory / written material)
1. Linguistic working memory	1. Word comprehension, visual recognition	- pointing out presented words (auditory) and word series from the pictures
	2. Word series recall	- repeating word series presented (auditory)
	3. Sentence recall	- repeating sentences presented (auditory)

	4. Story recall, information units	- repeating the story presented (auditory), produced information units are counted
	5. Story recall, questions	- answering questions about the story presented (auditory)
2. Language comprehension	6. Complex grammatical structures	- answering questions containing complex grammatical structures (auditory)
	7. Metaphorical interpretation	- choosing the correct interpretation of three choices for metaphors presented (written)
	8. Logical reasoning	- following instructions (written)
3. Language production	9. Sentence production	- producing a meaningful sentence out of presented basic words (written)
	10. Word fluency	- producing as many words as possible in 60 seconds for different categories (clothing, cities, verbs, adjectives, and two different letters given) (auditory)
	11. Definitions	- defining concepts presented (written)

Table 2. Results of two-sample *t*-test and Descriptive Statistics for FA-values (DTI) between DAI (n = 44) and healthy control (n =67) group.

Variable	DAI		Control		Mean Difference (95% CI)	t	df	p
	Mean	SD	Mean	SD				
Right SLF	0.511	0.027	0.505	0.026	0.005 (-0.005, 0.016)	1.058	109	0.293
Left SLF	0.506	0.026	0.520	0.029	-0.014 (-0.025, -0.004)	-2.652	109	0.009
Left AF	0.523	0.028	0.541	0.028	0.018 (-0.029, -0.007)	-3.300	109	0.001
Right SLF+front-gesch	0.505	0.026	0.501	0.030	0.004 (-0.007,0.015)	0.776	109	0.439
Left SLF+front-gesch	0.527	0.029	0.542	0.028	-0.016 (-0.027, -0.005)	-2.877	109	0.005
Right AF+tempor-gesch	0.478	0.042	0.474	0.041	0.005 (-0.011, 0.021)	0.590	109	0.556
Left AF+tempor-gesch	0.525	0.029	0.541	0.031	-0.016 (-0.028, -0.005)	-2.778	109	0.006

SLF, Superior longitudinal fasciculus
 AF, Arcuate fasciculus
 SLF+front-gesch, frontal connections of arcuate fasciculus to lower parietal cortex
 AF+tempor-gesch, temporal connections of arcuate fasciculus to lower parietal cortex

Table 3. Pearson correlations between the cognitive-linguistic outcome and the FA values (DTI) in the DAI group (n = 44).

DTI variable	Cognitive-linguistic variable					
	Linguistic working memory		Language comprehension		Language production	
	R	p	R	p	R	p
Right SLF	-0.15	0.320	-0.33	0.030	-0.15	0.319
Left SLF	-0.19	0.229	-0.32	0.035	-0.17	0.282
Left AF	-0.17	0.278	-0.27	0.080	-0.10	0.520
Right SLF-+front-gesch	-0.19	0.211	-0.32	0.037	-0.40	0.008
Left SLF+front-gesch	-0.12	0.440	-0.23	0.136	-0.17	0.282
Right AF+tempor -gesch	-0.18	0.246	-0.42	0.005	-0.34	0.022
Left AF+tempor-gesch	-0.12	0.432	-0.17	0.264	-0.23	0.136

SLF, Superior longitudinal fasciculus
 AF, Arcuate fasciculus
 SLF+front-gesch, frontal connections of arcuate fasciculus to lower parietal cortex
 AF+tempor-gesch, temporal connections of arcuate fasciculus to lower parietal cortex