MULTIPLE DISRUPTION OF THE BODY REPRESENTATION IN NEGLECT

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Background and purpose – Neglect related to the body has many symptoms. We suggest that the various symptoms might be associated with the injuries of different cognitive functions referring to the body, which are caused by lesions of different brain areas. Therefore we investigated the injuries of two functions in a group of patients with neglect (N=10) contrary to patients without neglect (N=10) and healthy controls (N=10). These functions are: perception of body location in external space and the perception of body shape.
Methods – We applied a novel method (Body Portraying Method), which is suitable for measuring subjective perception of both body location and body shape.
Results – 1. Patients with left neglect perceived their bodies with a significant right shift compared to their real body position. In contrast to this, patients without neglect and healthy controls tended to shift the subjective location of their body to the left. 2. Patients with neglect perceived the shape of their bodies significantly more distorted than both patients without neglect and healthy controls. 3. In case of eight patients with neglect, the symptom of shifted body location to the right and the symptom of body shape distortion appeared together. However, injuries of these two functions dissociated in case of two neglect patients.
Conclusions – Both the perception of body location in external space and the perception of body shape might become distorted in neglect. Furthermore, the dissociation of these symptoms supports our suggestion, that they might be associated with the injuries of different functions referring to the body. This result has practical issues as well. At the end of the study we discuss the necessity of appropriate tailored physiotherapy (fitted to the injured function) in the rehabilitation of patients with neglect.

Keywords: *brain injury, neglect, body representation, tailored physiotherapy*

A TEST LEKÉPZŐDÉSÉNEK TÖBBSZÖRÖS KÁROSODÁSA NEGLECT SZINDRÓMÁBAN

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Háttér és cél – A testre vonatkozó neglectnek sokféle tünete ismert. Tanulmányunkban feltételezzük, hogy a különböző tünetek mögött más-más testhez kapcsolódó funkció és ezzel együtt más és más agyi terület károsodása állhat. Ennek feltárásához két funkció károsodását vizsgáltuk neglecttel küzdő betegeknél (n=10), összehasonlítva egészséges személyekkel (n=10) és neglectes tüneteket nem mutató betegekkel (n=10). A kérdéses funkciók: a test térbeli helyzetének megítélése és a testforma észlelése.
Módszer – A test leképződésének vizsgálatára új módszert használtunk: a testábrázolás módszerét, amely alkalmas az említett két testi funkció együttes mérésére.
Eredmények – 1. Bal oldali neglectes betegek testük térbeli helyzetét szignifikánsan jobbra tolódva észlelték a valós testhelyzetükhöz képest. Ezzel szemben a neglectes tüneteket nem mutató betegek, valamint az egészséges kontrollszemélyek hajlamosak voltak balra eltolni testük észlelt helyzetét. 2. A neglectes betegek testük formáját szignifikánsan torzultabbnak észlelték, mint az egészséges kontrollszemélyek és a neglectes tüneteket nem mutató betegek. 3. Nyolc neglectes beteg esetében a test szubjektív jobbra tolódása és a testforma torzult észlelése együtt jelentkezett, viszont a két funkció sérülése disszociált két neglectes beteg esetében.
Következtetések – Vizsgálatunk egyrészt igazolta, hogy a test térbeli helyzetének megítélése és a testforma észlelése károsodik neglect esetén. Másrészt a két tünet disszociációja megerősíti, hogy feltételezhetően ez a két tünet két különböző funkció károsodásához köthető. Az eredményeknek gyakorlati következményei is vannak. Tanulmányunk végén tárgyaljuk az egyedi – károsodáshoz illesztett – terápiás stratégiák szükségességét a neglectes betegek mozgásrehabilitációjában.

Kulcsszavak: *agykárosodás, neglect, testreprezentáció, egyedi mozgásterápia*

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Both neglect syndrome and the neural representation of the body are complex phenomena. For a review see *Verseghi* and *SNagy*[1] and *Longo*, *Azanón* and *Haggard*[2]. Unilateral neglect is defined as a "failure to report, respond, or orient to novel or meaningful stimuli presented to the side opposite the brain lesion when this failure cannot be attributed to either sensory or motor defects"[3] (p. 268). It may affect personal space (own body), as well as extrapersonal space (as several different words are used in the literature for indicating different portions of the space, in this paper – according to *Guariglia* and *Antonucci*[4] – we will indicate the subject 's body as personal space and both reaching space (peripersonal space) and far space as extrapersonal space). Both neuropsychological studies[4, 5] and lesion analysis[6] supports the dissociation between these two aspects of neglect. Although it is also known, that neglect related to the body is more often associated with, than double-dissociated from extrapersonal neglect[6, 7]. In this paper we focus on neglect associated with personal space.

There are various symptoms of neglect associated with body. The most obvious one is when patients are completely non-conscious of the contralesional half of their bodies. For instance, they do not take care of it, do not dress the concerned limbs, lay or sit on their hands, or hurt the contralesional side of their bodies without noticing. This phenomenon is called personal neglect syndrome[7, 8]. However, there is another specific form of neglect related to the body, which is known in the current literature as somatosensory neglect. Symptoms of somatosensory neglect are[9]:

1. Ignoring of tactile stimulation (i.e. touch) or painful stimuli (cold/hot stimuli, jammed fingers in wheel or spokes of the wheelchair) on the contralesional body half including tactile extinction as well.
2. Mislocalization of tactile stimuli on the contralesional side of the body (e.g. allochiria, alloesthesia).
3. Subjective shift of own body-midline (i.e. position of the spine) to the ipsilesional side.

Personal and somatosensory neglect are not entirely equivalents of each other, but there is a significant overlap between them. They both refer to the personal space and include disregards of sensory information. Personal neglect, however, does not only have sensory components but also motor symptoms as well, whereas somatosensory neglect refers to sensory disregard as well as to spatial mislocalization of stimulation on body surface. Another telling argument for the strong connection between these two aspects of neglect is that both of them can be considered a disorder of body representation.

There is a widespread agreement that there are multiple mental representations of the body in the brain[2, 10-14]. Many attempts have been made to create a taxonomy of different types of body representation. For a review, see *de Vignemont*[15]. There is one aspect on which almost all taxonomies seem to agree, that various body representations might represent different functions associated with the body (e.g. perception of body shape, perception of body surface, guidance of actions). We suggest that the aforementioned symptoms of personal and somatosensory neglect can be understood as disruptions of different functions. In **Table 1.** we present some functions related to the body that might be injured in neglect associated with personal space.

Accordingly, assuming that neglect associated with the body can be considered a body representation disorder, in this paper we examined the body representations of patients with neglect. In contrast to previous studies – that usually focused on examining representations of the hand[8, 21] – we examined the representation of the entire upper body, since the perception of the trunk in external space might be a key element in the process of relearning walking, and hereby its injury might significantly influence the process of rehabilitation.

We applied a novel method (Body Portraying Method) to measure the subjective perception of the body[22, 23]. This task is nonverbal, because it was designed to evaluate the perception of the own body over what one thinks about his body. The basic idea of the tool is that a person – based on his own perception – has to portray his own body by a few typical body spots. Different body parts of the subjects are touched by the experimenter, and the participants need to point with their fingers the locations of the equivalents of the touched body spots on a paper hanging front of them.

In this paper first we investigated the extent of an overall disruption of body representation in neglect. However, a general body representation disturbance may have many underlying reasons. It may arise, for instance, from a subjective shift of body location in the horizontal and/or in the vertical dimension, as well as from the disruption of perceived body shape.

Body Portraying Method is a suitable task to investigate how people perceive the location of their body and body parts in the external space. Results of studies conducted among people with hemispatial neglect show that patients with left neglect locate the midline of their trunks with a right shift[18]. Additionally, other studies indicate, that when patients with neglect evaluate a subjective straight ahead orientation, a horizontal shift to the

Table 1. *Functions injured in neglect associated with body*

Neglect specific symptoms	Injured functions related to the body
1a. Ignoring stimulations on the contralesional body half[4, 9] 1b. Tactile extinction: being unaware of tactile stimuli on contralesional body surface during bilateral simultaneous stimulation, although the sensation of tactile stimuli remains intact on both halves of the body[16]	1. The processing of somatosensation[2]
2a. Allochiria: mislocation of sensory stimuli to the corresponding opposite half of the body or space[17] 2b. Alloesthesia: displacement of stimuli to a different point on the same extremity[17]	2. The localization of stimuli on the body surface[10]
3a. Subjective shift of own body-midline to the ipsilesional side in external space[18] 3b. A horizontal shift to the ipsilesional side in strait ahead orientation[19]	3. Perception of body location and body orientation[10]
4. Motor neglect: the existence of spontaneous non-utilisation or underutilisation of the limbs on contralesional side of the body, although muscular strength, reflexes or sensibility remain intact[20]	4. Guidance of action[13, 14]
5. Non-consciousness of the contralesional half of the own body[7]	5. Consciousness of own body[2, 10]
6. Difficulties in drawing a person or in reconstructing body using pre-cut puzzle pieses[4]	6. Semantic knowledge about arrangement of body parts[2]

ipsilesional side appears[19]. One explanation for these findings is the "hemispatial hypothesis" suggested by *Heilman*, *Bowers* and *Watson*[18]. According to this, the right hemisphere is responsible for intention into left hemispace and the left hemisphere is responsible for intention into right hemispace. If both hemispheres are intact, the system is balanced. Whereas, when only one hemisphere is damaged, the other half of the brain remains unopposed, thus the subjective straight ahead orientation deviates into the ipsilesional hemispace. *Ferber* and *Karnath* note, that the online visual perception normally interacts with the representation of hemispace in the perception of straight ahead orientation[19]. That means that both the parietal lobe (which is responsible for the integration of various inputs that are involved in neural representation of space) and the occipital cortex (which is responsible for the primary neural processing of visual perception) are involved in evaluating the body orientation in the horizontal dimension. *Ferber* and *Karnath* investigated subjective straight ahead orientation in both cases of patients with left hemispatial neglect (a disturbance of spatial representation) and patients with left hemianopia (a disturbance of visual perception)[19]. They found that injury of the parietal cortex, causing neglect, might cause an ipsilesional shift of straight ahead orientation. Whereas the lesions of occipital cortex, causing primary visual field defect, lead to a contralesional deviation of straight ahead orientation. Thus, the aforementioned hemispatial hypothesis seems to be apply only to the functioning of the parietal cortex. Authors do not discuss the possible mechanism underlying contralesional shift of subjective straight ahead orientation in the case of homonymous hemianopia.

In this paper we put special emphasis on examining the horizontal shift of the body location in external space in the case of patients with neglect. To eliminate the influence of visual field defect on body portraying, the task was carried out blindfolded, thus the participants can only rely on pure somatosensory information during the portrayal. (Originally the Body Portraying Method consists of two settings: first it has to be carried out blindfolded, then with eyes open. In this study we present the results of the blindfolded setting.) Thus, we can expect a horizontal shift in body portraying toward the ipsilesional (right) side. In contrast to previous studies, which focused on the shift of body midline, we examine the direction of the shift of the body contour as well. The reason for this is that the body has not only axis but also latitude. We suppose that perception of body boundaries might differ from the perception of body axis.

The Body Portraying Method also enables the investigation of perception of body shape as well. However, this function is poorly investigated in association with neglect. Multilevel representations of body shape are distinguished in the scientific literature[2]. There might be a (1) non-conscious, somatosensory, (2) a more-conscious visual-somatosensory and (3) an abstract, semantic level

Table 2. *Description of the tasks used in this study for measuring extrapersonal neglect and the possible symptoms of extrapersonal neglect related to each task*

Name of the task	Description of the task	Possible symptoms of extrapersonal neglect related to the given task
Bells test[25]	Patients need to find 35 figures of a bell among distracting items.	Centre of Cancellation (CoC) indicates the centre of mass for all the detected items. This measure is sensitive to both the number of omissions and the location of these omissions. CoC scores higher than 0.09 in the Bells Test were regarded as an indication of extrapersonal neglect behaviour (for the calculation we used the procedure and software by *Rorden* and *Karnath*[26]; www.mricro.com/cancel/)
Line bisection task	Patients were asked to mark the midpoint of twelve horizontal lines of varying lenght (2, 4, 6, 8 cm long lines on one page, each length are represented with three lines).	One symptom of neglect was the omission of any lines on the left side of the paper. Another variable of the neglect was the mean of the signed values of the distances between the real midpoints and the marks made by the subjects (mm; negative sign meant left shift, positive sign meant right shift). A cut-off score of shift of 17 mm was used, because none of 57 healthy persons made an error greater than 17 mm (Verseghi, unpublished data).
Clock-drawing task	Patients were asked to draw from memory a large clock face with all the numbers.	According to *Baily*, *Riddoch* and *Crome* the hallmark of neglect was an incomplete drawing with more numbers on the one side than the other (even though a whole circle may have been drawn)[28].
Verseghi Spatial Complex Figure Test[27]	Patients were instructed to copy a drawing of a complex figure. A few minutes after the copying task, they were asked to draw the figure from memory.	Symptom of neglect was the omission of any elements on the left side of the figure during copying the Spatial Complex Figure.

of body shape representation in the brain. *Guariglia* and *Antonucci*[4] showed in their case study, that the conscious, semantic knowledge about body shape might disrupt in personal neglect. In this study we investigate whether the "knowledge" about the shape of the own body is also distorted on a somatosensory level in the case of patients with neglect.

Earlier we mentioned our suggestion that various symptoms of neglect related to the body might be associated with disruptions of different functions linked to the body. Some studies suggest that the two body representations investigated in this paper might be represented separately in the brain[2, 24]. Thus, we can expect to find dissociation – even double dissociation – between the disruption of evaluated body location and distortion of perceived body shape.

As we mentioned before, the neglect related to the body is often associated with extrapersonal neglect. Thus, in this study we examined the body representations of patients with extrapersonal neglect, compared to the body representations of both patients without extrapersonal neglect and healthy controls.

Material and methods

PARTICIPANTS

Twenty right-handed patients with subacute brain injury (mean time since brain injury: 87.11 days) and ten right-handed healthy control subjects participated in the study. Ten patients had right hemisphere lesions with left extrapersonal neglect (PN+), ten patients had left hemisphere lesions without extrapersonal neglect (PN–). None of the subjects had haemianesthesia nor atopognosia (patients had no difficulties in localizing single tactile stimuli on both side of body surface). We assessed the presence of extrapersonal neglect by the Bells test[25, 26], by a line bisection task, by clock-drawing task and by the Verseghi Spatial Complex Figure test[27]. Patients were diagnosed with extrapersonal neglect if they showed symptoms of neglect in at least two of the above mentioned tasks. The description of these tasks and the possible symptoms of extrapersonal neglect related to each task are presented in **Table 2**.

Demographic and clinical data are provided in **Table 3**. As illustrated in this table, the groups of

Table 3. *Demographic and clinical data for patients with right hemisphere lesions and neglect (PN+), left hemisphere lesions without neglect (PN–) and healthy controls*

		PN+ (N=10)	PN– (N=10)	Controls (N=10)	Statistics
Age	Mean	57.5 (SD=16.59)	58.9 (SD=20.12)	58.7 (SD=4.17)	F(2,18.253)=0.025* p=0.976
Sex	Female	5	6	5	χ^2=0.268 p=0.875
	Male	5	4	5	
Type of brain injury	Stroke	8	8	-	χ^2=0.000 p=1
	Traumatic	2	2	-	
Post-injury period	Mean (days)	87.75 (SD=48.7)	86.6 (SD=57.93)	-	t(16)=0.045 p=0.965

* Brown-Forsythe one-way variance analysis, because variance homogeneity is violated.
SD = standard deviation

patients and healthy controls were comparable with respect to age and sex. Statistically, patients with neglect and patients without neglect were comparable with regard to type of brain injury and post-injury period.

EXAMINATION OF BODY REPRESENTATION

Body representation was assessed by a tool (Body Portraying Method) created by two of the present authors *(Anna Verseghi* and *Zita SNagy)*[22, 23]. The basic idea of the tool is that the shape of the body can be represented by a few typical spots (top of the head, neck, shoulder, armpit, waist, elbow and several spots along the spine) and we can observe how patients portray their bodies using these spots **(Figure 1.)**.

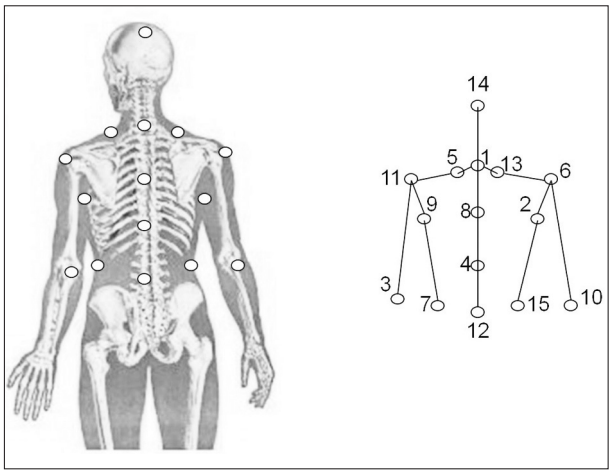

Figure 1. *Schematic portrayal of the body using typical points. Numbers next to the body spots represent the sequence of portrayal*

PROCEDURE

Subjects were seated blindfolded in front of a large sheet of paper (1m × 1.2m) hanging on a wall. They received the following instructions: "Imagine that you are sitting in front of a mirror. I will touch a few spots on your body. As if you were seeing yourself in that mirror, please point out on the paper where these touched spots would be in the mirror." Then the experimenter, standing behind the participants, touched in a strict order the different spots on their bodies **(Figure 1.)**. The participants had to point with their fingers on the paper the locations of the equivalents of the touched body spots. The experimenter marked these spots and its numbers with a pen. At the end of the portrayal, we asked them to remain still in the same body position, and we recorded the real position (the perpendicular projections of the touched spots) of the body on the paper.

We used a transparent graph paper (1m × 1.2m) to read the coordinates of the portrayed spots (the co-ordinate axes were the left and the button edges of the paper), thus we were able to create the computerized portray with Microsoft Excel. In **Figure 2.** we show an example for a body portrayal of a healthy subject.

VARIABLES

For measuring an overall disruption of body representation we calculated a general variable: we took the mean of the distances (cm) between the portrayed and real positions of each spots of body contour (neck, shoulder, armpit and waist).

As a second step, we examined the subjective perception of body location in external space separately on both the x-axis and the y-axis. We made our calculations by computing the mean of the absolute values of the horizontal and vertical shifts (which is meant to be the distance (cm) between the

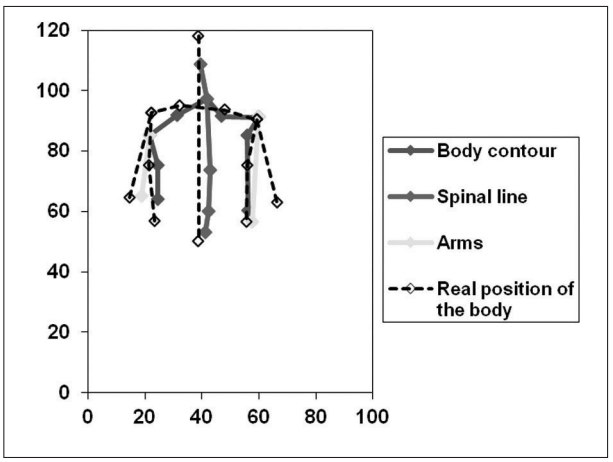

Figure 2. *Example for a body portrayal of a healthy subject. The right side of the body portrayal represents the right half of the subject 's body. Solid lines show the body portrayal created by the subject; broken lines show the real position and shape of the subject's body*

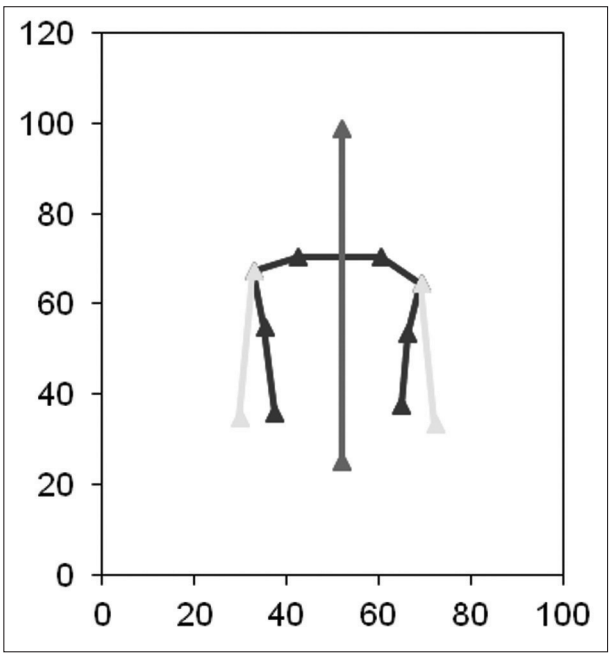

Figure 3. *Illustration of a perfectly drawn upper body shape for the judges, who was asked to evaluate the shape of the body portrays on a seven-point Likert scale*

portrayed and real positions of the body contour on both x-axis and y-axis).

As one of the symptoms of somatosensory neglect is the ipsilesional shift of perception of the body midline, we also investigated the direction of the subjective shift of body portrayal on the x-axis. We examined the direction of the shift of body midline (four spots along the spinal line and the spot of top of the head) as well as that of the body contour (spots of neck, shoulder, armpit and waist). We calculated our variables by figuring the mean of the signed value of the horizontal shifts (which is meant to be the distance between the portrayed and real positions of the body contour and midline on x-axis). The sign of the mean shows the direction of the shift (negative sign towards left, positive sign towards right).

In the examination of the distortion of perceived body shape, ten independent judges evaluated on a seven-point Likert scale how closely the body portrayals resembled a human upper body. The real position of the body was not marked on portrayals, and the judges received an illustration of a perfectly drawn body shape **(Figure 3.)**. We created a variable from the means of the scores given by the judges that represents the distortion of body shape (minimum score: 1 – perfectly portrayed body shape, maximum score: 7 – fully distorted body shape). In **Figure 4.** we show examples for the possible distortions of the variables.

Results

For the statistical analyses we used SPSS-15 (Statistical Package for Social Sciences) program. Assumption of normality was valid, but variance homogeneity was violated by all variables. Therefore we generally applied robust one-way analyses of variance with post hoc tests to evaluate group differences (Brown-Frosythe test and Games-Howell post hoc test), nonparametric Wilcoxon-tests to evaluate differences within groups, and one-sample t-test to analyze if the extent of the distortions are significantly bigger than zero.

GENERAL DISRUPTION OF BODY REPRESENTATION

Descriptive statistics of general disruption of body representation are presented in **Table 4**. Results of robust one-way ANOVA disclosed significant differences among groups ($F(2,27)=12.672$; $p=0.001$; $\eta^2=0.48$). Subsequent post hoc comparisons revealed that both of the patient groups showed significantly more distorted body portrayal than controls (PN+: $p=0.005$; PN–: $p=0.021$). Additionally, PN+ patients portrayed their body as significantly more disrupted than PN– patients ($p=0.031$). These results indicate that body representation disruption could occur after brain injury independently from the lateralization of the injury. However, the distortion of the body representation is significantly bigger in the group of patients with neglect than in the case of patients without neglect.

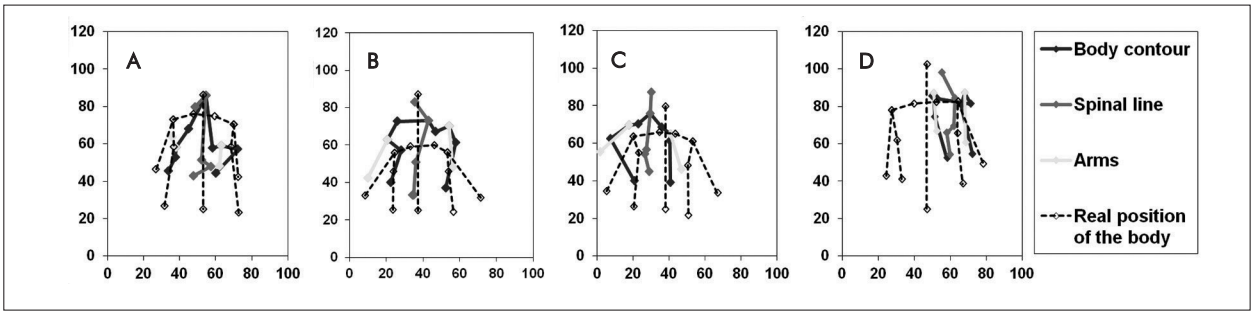

Figure 4. *Examples for the possible distortions of the examined variables. Panel* **A** *shows a portray with distorted body shape. Panel* **B** *shows a portray with a shifted body location on y-axis. Panel* **C** *shows a body portrayal with shifted body location on x-axis to the left. Panel* **D** *shows a body portrayal with shifted body location on x-axis to the right. The right side of the body portrayal represents the right half of the subject's body. Solid lines show the body portrayal created by the subject; broken lines show the real position and shape of the subject's body*

Table 4. *Descriptive statistics of general disruption of body representation*

	PN+ (N=10)	PN– (N=10)	Controls (N=10)
Mean (cm)	20.43	11.43	8.23
Standard deviation	9.12	2.61	2.17
CI 95%	13.91–26.96	9.57–13.30	6.68–9.78

CI: confidence interval for mean; PN+: patients with neglect; PN–: patients without neglect

Table 5. *Extent of the shifts of body portrayal on x-axis and y-axis*

		PN+ (N=10)	PN– (N=10)	Controls (N=10)
x-axis	Mean (cm)	10.40	5.43	4.59
	Standard deviation	5.38	2.2	2.03
	CI 95%	6.56–14.25	3.86–6.99	3.14–6.05
y-axis	Mean (cm)	14.91	8.66	5.75
	Standard deviation	9.97	3.24	1.62
	CI 95%	7.78–22.04	6.34–10.98	4.58–6.91

CI: confidence interval for mean; PN+: patients with neglect; PN–: patients without neglect

EXTENT OF THE SHIFTS OF BODY PORTRAYAL ON X-AXIS AND Y-AXIS

The extent of the shifts of body portrayal on x-axis and y-axis in every group are presented in **Table 5**. Results of a one-sample t-test showed that the extent of the horizontal shifts of body location were significantly bigger than zero in the case of both patients groups as well as in the case of healthy controls (PN+: $t(9)=6.117$; $p=0.000$; $d=1.93$; PN–: $t(9)=7.813$; $p=0.000$; $d=2.47$; Controls: $t(9)=7.152$; $p=0.000$; $d=2.26$). The extent of the vertical shifts of body location were also significantly bigger than zero in the case of all groups (PN+: $t(9)=4.728$; $p=0.001$; $d=1.5$; PN–: $t(9)=8.453$; $p=0.000$; $d=2.67$; Controls: $t(9)=11.185$; $p=0.000$; $d=3.55$). On the other hand, results of a robust one-way ANOVA disclosed significant differences among groups considering the extent of the shift of body location in external space on both axis (on x-axis: $F(2, 27)=7.817$; $p=0.005$; $\eta^2=0.37$; on y-axis: $F(2, 27)=5.842$; $p=0.018$; $\eta^2=0.3$). Subsequent post hoc comparisons revealed that PN+ patients portrayed their body with a significantly larger shift on x-axis than both Controls ($p=0.02$) and PN– patients ($p=0.047$). In addition, the difference between PN– patients and Controls was non-significant ($p=0.658$). In contrast, on y-axis PN+ patients portrayed their trunk with a significantly bigger shift than Controls ($p=0.042$), but not than PN– patients ($p=0.189$). Furthermore PN– patients portrayed their trunk with a larger shift than Controls at

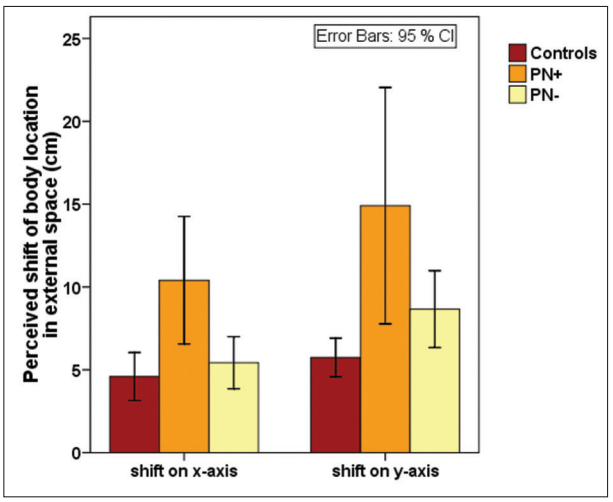

Figure 5. *Differences between patient groups and controls considering the shift of perceived body location in external space on both axes. PN+ patients portrayed their body with a significantly larger shift on x-axis than both Controls (p=0.02) and PN– patients (p=0.047). In addition, the difference between PN– patients and Controls was non-significant (p=0.658). On y-axis PN+ patients portrayed their trunk with a significantly bigger shift than Controls (p=0.042), but not than PN– patients (p=0.189). In addition, PN– patients portrayed their trunk with larger shift than Controls at tendency level (p=0.059). (PN+: patients with neglect; PN–: patients without neglect)*

tendency level (p=0.059). These results indicate that significant horizontal and vertical shifts of body location in external space might occur not only following brain injury, but also in the case of healthy person. However, patients following brain injuries perceive their bodies with a larger vertical shift than healthy controls (although the difference between patients without neglect and healthy controls showed only a tendency). In addition, patients with neglect – in contrast to patients without neglect – evaluate the location of their bodies also horizontally more shifted than healthy controls **(Figure 5.)**.

DIRECTION OF THE SHIFT OF BODY CONTOUR AND SPINAL LINE ON X-AXIS

Means and Standard deviations are presented in **Table 6**. As **Figure 6.** illustrates, the difference between portrayal of body contour and spinal line was non-significant (Z=-0.134; p=0.894).

A One-sample t-test was done to analyze whether the shifts of the spinal line and the body contour were significantly bigger than zero. PN+ patients portrayed their spinal lines and their body contour with a shift to the right (spinal line: t(9)=2.571; p=0.03; d=0.81; body contour: t(9)=2.041; p=0.072; d=0.65). However, the shift of

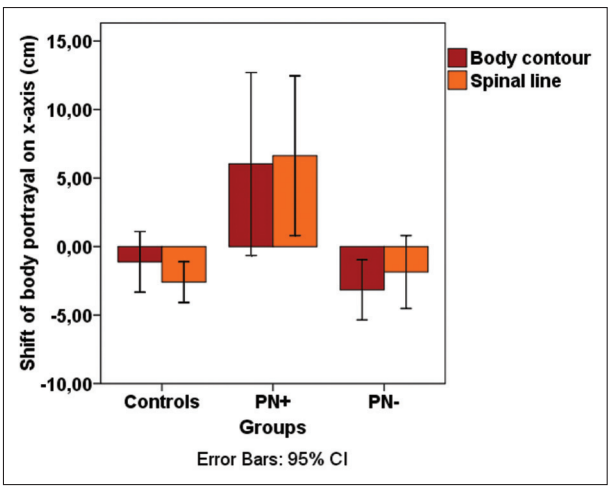

Figure 6. *Differences between patient groups and controls considering the direction of the shift of perceived body location in external space on x-axis. PN+ patients portrayed their spinal lines (p=0.03) and their body contour (p=0.072) with a shift to the right. The shift of the spinal line in the case of PN– patients was non-significant (p=0.148), however, they portrayed their body contour with a significant shift to the left (p=0.01). Controls pointed their spinal lines with significant shifts to the left (p=0.003), in addition, the shift of the body contour was non-significant (p=0.282). Negative sign means shift towards left, positive sign means shift towards right. (PN+: patients with neglect; PN–: patients without neglect)*

Table 6. *Direction of the shift of body contour and spinal line on x-axis*

		PN+ (N=10)	PN– (N=10	Controls (N=10)
Spinal line	Mean (cm)	6.63	-1.85	-2.6
	Standard deviation	8.15	3.73	2.08
	CI 95%	0.79 – 12.46	-4.52 – -0.8	-4.09 – -1.11
Body contour	Mean (cm)	6.03	-3.16	-1.12
	Standard deviation	9.34	3.07	3.09
	CI 95%	-0.65 – 12.70	-5.36 – -0.97	-3.33 – 1.09

The sign of the mean shows the direction of the shift: negative sign towards left, positive sign towards right.
CI: confidence interval for mean; PN+: patients with neglect; PN–: patients without neglect

Table 7. *Descriptive statistics of the scores of disruption of body shape given by the judges*

	PN+ (N=10)	PN– (N=10	Controls (N=10)
Mean	5.98	4.51	3.78
Standard deviation	1.05	1.23	0.58
CI 95%	5.23–6.73	3.63–5.39	3.37–4.19

Minimum score: 1 – perfectly portrayed body shape, maximum score: 7 – fully distorted body shape.
CI: Confidence interval for mean; PN+: patients with neglect; PN–: patients without neglect

the body contour showed only a tendency, whereas the effect size was medium. The shift of the spinal line in the case of PN– patients was non-significant, and the effect size was small (t(9)=-1.582; p=0.148; d=0.49), but they portrayed their body contour with a significant shift to the left (t(9)=-3.263; p=0.01; d=1.03). Controls pointed their spinal lines with significant shifts to the left (t(9)=-3.941; p=0.003; d=1.25); the effect size was large. The shift of the body contour in the case of controls was non-significant, and the effect size was small (t(9)=-1.144; p=0.282; d=0.36).

These results indicate that not only patients with neglect but also healthy controls and patients without neglect might perceive their bodies with a significant horizontal shift. However, the shift directs typically rightwards in the case of patients with neglect contrary to patients without neglect and healthy controls, who tend to perceive their bodies with a subjective left shift.

DISRUPTION OF BODY SHAPE IN NEGLECT

In this study, the variable of the subjective perception of body shape consists of the mean of the scores given by the independent judges. The reliability of the judgments was high, Cronbach α=0.962. Descriptive statistics of disruption of body shape are presented in **Table 7**. Results of robust one-way ANOVA disclosed significant differences among groups considering the disruption of perceived body shape (F(2, 27)=12.812; p=0.000; η^2=0.49).

Subsequent post hoc comparisons revealed that PN+ patients showed significantly more distorted body shape than both Controls (p=0.000) and PN– patients (p=0.026). The difference between PN– and Controls was non-significant (p=0.243). These results show that the perception of body shape could become distorted following a right hemispheric brain injury with neglect symptoms. We did not get the same results after left hemispheric brain injury without neglect.

RELATION OF THE DISTURBANCE OF THE PERCEPTION OF BODY SHAPE AND OF THE PERCEPTION OF BODY LOCATION

We also investigated the associations of the two symptoms that only appeared within the group of patients with neglect. These were the disruption of body shape and the subjective horizontal shift of the own body to the right. We found that these symptoms may appear either separately or together.

Within the PN+ groups we conducted case studies, using a modified version of the t-test of *Sokal* and *Rohlf* considering the low number of controls[29, 30]. Results show, that within the group of patients with neglect (N=10) there were seven patients who showed disrupted perception of both body form and body location. There was one patient who did not show any disruption of body representation, and there were two patients who showed disrupted perception of body shape, but the perception of body location remained intact **(Table 8.)**. None of the patients portrayed their bodies with a significant right shift together with an intact body shape. These results support that extrapersonal neglect is not always associated with the disruption of body representation. In our case, one out of ten patiens with extrapersonal neglect showed no evidence of a disturbed body representation. More importantly, we found dissociation – but not double dissociation – between injury of perception of body shape and the injury of perception of horizontal body location in external space. On **Figure 7**. we show examples for this phenomenon.

Discussion

In this paper we investigated the disruption of body representation in hemispatial neglect. Our results show that the disruption of body representation is not a specific symptom for neglect syndrome, because it might follow brain injury independently of the lateralization of the injury. The distortion of the body representation, meanwhile, is significantly

Table 8. *Body shape scores and the extent of horizontal right shift of body within PN+ group, additionally results of comparison of individual 's score against control group*

Patients	Disruption of body shape		Horizontal shift of the body (+: right –: left)	
	score	modified t-testa	cm	modified t-testa
PN+1	6.8	t (9)=4.965; p<0.001	-3.15	t (9)=-0.626; p>0.1
PN+2	6.5	t (9)=4.471; p<0.001	9.1	t (9)=3.154; p<0.001
PN+3	5.1	t (9)=2.17; p<0.05	14.59	t (9)=4.848; p<0.001
PN+4	5.4	t (9)=2.66; p<0.05	-0.81	t (9)=0.096; p>0.1
PN+5	6.3	t (9)=4.143; p<0.001	18.58	t (9)=4.965; p<0.001
PN+6	7	t (9)=5.293; p<0.001	-9.36	t (9)=-2.543; p<0.05
PN+7	6.9	t (9)=5.129; p<0.001	7.49	t (9)=2.657; p<0.05
PN+8	3.7	t (9)=-0.132; p>0.1	0.75	t (9)=0.577; p>0.1
PN+9	6.6	t (9)=4.635; p<0.001	18.09	t (9)=5.927; p<0.001
PN+10	5.5	t (9)=2.828; p<0.05	4.99	t (9)=1.885; p<0.05

A modified t test of Sokal and Rohlf considering the low number of controls[29, 30].

bigger in the group of patients with neglect than in the case of patients without neglect.

The general distortion of body portrayal may have many underlying reasons. In the current study we focused on two of them: the disruption of the perception of body location in external space and the distortion of perceived body shape.

Previous studies showed that the evaluation of body orientation in the horizontal dimension disrupts in neglect[18, 19]. Our results show that a significant horizontal shift of body location in external space might occur following both right and left hemispheric brain injury, moreover also in the case of healthy person. However, patients with neglect perceive their bodies with a significantly larger horizontal shift than both healthy controls and patients without neglect. Furthermore, the shift directs typically rightwards in the case of patients with left hemispatial neglect contrary to patients without neglect and healthy controls, who tend to perceive their bodies with a subjective left shift. These results correspond to the findings of *Heilman*, *Bowers* and *Watson*[19]. The reason for the asymmetry in the evaluation of horizontal body orientation in the case of the controls is unknown. *Heilman*, *Bowers* and *Watson* suggest that perhaps right hemispheric activation induces increased intention to contralateral (left) hemispace. The body portraying task is a spatial task which also activates body representations. Normally, completion of the task might cause increased activity in the right hemisphere, and this activation might cause an increased intention toward the left hemispace.

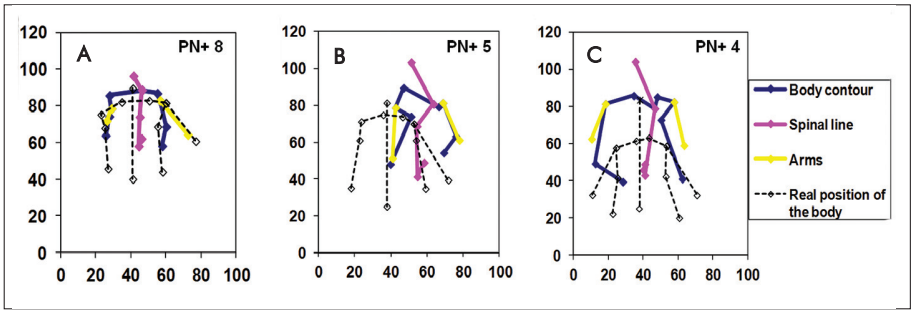

Figure 7. *Dissociation between disruption of body shape and subjective horizontal shift of own body to the right in the group of patients with neglect. The distorted portrayal of body shape and the perception of shifted body location may appear either separately or together. Panel* **A** *shows a body portrayal with neither shape distortion and nor shifted body location compared to healthy controls. (Shape distortion score: 3.7; p>0.1; Shift: 0.75 cm; p>0.1) Panel* **B** *shows a body portrayal with both distorted body shape and shifted body location compared to healthy controls (Shape distortion score: 6.3; p<0.001; Shift: 18.58 cm; p<0.001). Panel* **C** *shows a body portrayal with distorted body shape, but without shifted body location compared to healthy controls (Shape distortion score: 5.4; p<0.001; Shift: -0.81 cm, p>0.1). The right side of the body portrayal represents the right half of the subject 's body. Solid lines show the body portrayal created by the subject; broken lines show the real position and shape of the subject 's body*

We examined the direction of the subjective shift of the body along two variables. Perception of body midline and body contour was similar in the case of patients with neglect; both were perceived with a right shift. In contrast, patients without neglect perceived only their body contour, while controls perceived only their spinal line with a significant shift. We cannot exclude that these results might derive from the small sample size. However, it also could be a characteristic of the method, where subjects have to reach over the body midline half of the times during the portrayal,

because they use only one hand for pointing the body spots. There might be then again another explanation: the increase of the perception of one side of the body could be a result of the different sizes of cortical representations of the dominant and non-dominant body halves. To answer these questions further research is required.

Our results also show that a significant vertical shift of body location in external space might occur not only following brain injury, but also in the case of healthy persons. Both patient groups perceive their bodies with a larger vertical shift than healthy controls, although the difference between patients without neglect and healthy controls showed only a tendency. We suggest that these results were influenced by the experimental setting that subjects were sitting in during the body portrayal task. For the evaluation of the height of our body, standing upright might be a more relevant position. Thus, distortion of perceived height might be a secondary symptom of brain injury, which is caused by the fact that the patient cannot stand up. Further research is required to investigate this question.

Considering the perception of body shape, our results show that patients with neglect portray their bodies with a significantly more distorted shape than both patients without neglect and healthy controls. Furthermore the difference between patients without neglect and controls was non-significant. One explanation of this result might be that the shape of the body is represented in the parietal lobe[2], furthermore it is known that somatosensory bodily awareness is strongly associated with the activation of the right hemisphere[31].

According to our results, both the shift of body location to the right and the distortion of perceived body shape occurred only in the case of patients with neglect. However, our results also show that these two symptoms are not typical for every patient with neglect. Although 90% of the patients with extrapersonal neglect show at least one of these symptoms, 10% show none of them. These results support those studies that suggest that the neglect related to the body might dissociate from extrapersonal neglect[4–6]. Then again, we note that in this study there was no brain injured patient with right lateralization, who did not have the symptoms of extrapersonal neglect. Therefore further examinations are required to clarify whether the right horizontal shift of body location and the distortion of perceived body shape are specific symptoms of neglect, or if they are simply associated with the injury of the right hemisphere.

Finally our results also support the suggestion that the various symptoms of neglect associated with the body can be understood as disruptions of different functions relating to the body. There were two patients who – compared with healthy controls – portrayed their bodies with distorted shape but without horizontal shift. This result supports the dissociation between these two functions. On the other hand, we did not find double dissociation, since none of the patients with neglect portrayed their body with a significant right shift together with an intact body shape. One – and in our opinion the more plausible – explanation might be that our sample was too small (N=10) to find the kind of dissociation where solely the evaluation of body location is distorted. Another explanation might be that the perception of body shape and the evaluation of body location are different, but not independent components of body representation. However, this suggestion would not correspond to the current scientific theories of body representation[2, 24].

In the introduction we suggested one possible way of the connection between the symptoms of neglect associated with personal space and the injuries of the functions related to the body (see **Table 1.**). Further research is required to complete the list of the neglect specific symptoms, and to investigate the associations between the symptoms and the body representations. We believe that these kinds of investigations are important because they might have practical consequences. It is known that patients with neglect are more severely disabled in all daily activities and have poorer rehabilitation outcome than patients without neglect[32]. Presumably, tailored treatment strategies might enhance the effectiveness of rehabilitation. We suggest that injury of different functions might need different treatment strategies. Disruption of body location, for instance, might be treated by movement exercises in external space (e.g. passing by objects). On the other hand, various forms of sensory stimulation of the body surface (e.g. electric stimulation or massage) might improve perception of body surface, thus the perception of body shape. Accordingly, a revealing characteristic of the disturbance of body representation might be an important aspect in the development of individual treatment strategies for the rehabilitation of patients with hemispatial neglect.

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