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ABSTRACT

Introduction: Visual neglect is a frequent disorder following stroke and is often diagnosed by neuropsychological assessment. However, paper-and-pencil tasks have low predictive value as they lack sensitivity to capture neglect in complex, dynamic situations, such as activities of daily living. Aims of the current study were to assess the feasibility of the Mobility Assessment Course (MAC), a visual search multitask, to assess neglect, and its relation with existing neglect tasks. *Method*: Stroke patients admitted for inpatient rehabilitation and healthy controls were tested with the MAC in different corridors. Participants had to move through a corridor, finding and reporting 24 targets attached to the walls. In addition, the shape cancellation, line bisection, and Catherine Bergego Scale (CBS) were used in order to compare the MAC with existing diagnostic tools for neglect. *Results*: Administering the MAC was feasible, as 112 of 113 patients completed the MAC with a median duration of 4.09 min. Depending on the corridor where the assessment took place, in 88.5–93.3% of assessments all targets were visible. The number of omissions (total and contralesional) and the asymmetry score (contralesional–ipsilesional omissions) on the MAC as well as collisions and corrections, were higher for patients with neglect than for those without neglect. Depending on the neglect task used, 4.0–18.6% of patients without neglect on neuropsychological tasks or the CBS showed neglect on the MAC. Vice versa, 17.2–29.3% of patients who showed neglect at neuropsychological assessment or the CBS did not do so on the MAC. Finally, a moderate to strong positive relation was seen between neglect at neuropsychological assessment, the CBS, and the MAC. *Conclusions*: The MAC is an ecological task in which both quantitative and qualitative data on neglect can be collected. In order to assess the presence of neglect and neglect severity in a dynamic way, the MAC could be administered in conjunction with neuropsychological assessment.

1. Introduction

One prominent deficit following stroke is visuospatial neglect (commonly referred to as neglect). Patients with neglect fail—or are much slower—to orient toward, respond to, and report stimuli that occur at the contralesional side of space. In the acute phase following a stroke, approximately 50% of patients with right-hemisphere damage and 30% of patients with left-hemisphere damage show neglect (Chen, Chen, Hreha, Goedert, & Barrett, 2015). Within 3 months post-stroke onset, most recovery takes place; however, 40% of patients with neglect in the subacute phase show neglect 1 year post-stroke onset (Nijboer, Kollen, & Kwakkel, 2013). Neglect interferes with activities in daily life (Appelros, Karlsson, Seiger, & Nydevik, 2002) and is associated with poorer

functional as well as motor recovery (Adams & Hurwitz, 1963; Nijboer, Kollen, & Kwakkel, 2014; Nijboer, van de Port, Schepers, Post, & Visser-Meily, 2013), leaving patients with neglect more dependent on their environment than stroke patients without neglect (Buxbaum et al., 2004; Nijboer et al., 2013). As a result, proper diagnosis of neglect is regarded as highly important for goal setting in rehabilitation.

In general, neuropsychological paper-and-pencil tasks, such as cancellation or bisection tasks, are used in the diagnosis of neglect. Some patients, however, do not show neglect on paper-and-pencil tasks, but do during activities in daily life (ADL), such as washing or eating, especially in the chronic phase post-stroke onset when patients have learned compensatory strategies (Azouvi, 2016; Bonato, 2015; Huisman, Visser-

Meily, Eijsackers, & Nijboer, 2013; Ten Brink et al., 2013). There are several explanations for this discrepancy. First, neglect is a heterogeneous syndrome, varying in sensory modality (e.g., visual, auditory, and tactile neglect), distance (e.g., personal, peripersonal, and extrapersonal neglect), and frame of reference (e.g., egocentric or allocentric neglect) (Corbetta, 2014; Van der Stoep et al., 2013). Paper-and-pencil tasks are often designed to objectify *visual* neglect in *peripersonal* space. Second, in dynamic daily life situations, relevant stimuli have to be detected within a continuously moving environment in which one is also moving. There is little time to attend to objects, as stimuli are on the retina for a short amount of time, and there is strong competition between objects that draw attention (attention is drawn strongly to moving distractors). Objects on the neglected side, therefore, receive less attention and will be missed (Corbetta, Kincade, Lewis, Snyder, & Sapir, 2005; Rengachary, D'Avossa, Sapir, Shulman, & Corbetta, 2009). Finally, during paper-and-pencil tasks, patients can focus on one goal. When patients have to perform multiple operations simultaneously, such as walking, chatting, and looking, the attentional capacity is limited, and it is more likely that signs of neglect will be shown (Blini et al., 2016; Bonato, Priftis, Marenzi, Umiltà, & Zorzi, 2010; van Kessel, van Nes, Geurts, Brouwer, & Fasotti, 2013). To conclude, many factors are disregarded in standard paper-and-pencil tasks leading to a lack of sensitivity in the diagnosis of neglect.

In order to assess the presence of neglect and neglect severity in a more sensitive way, complementary tasks can be administered. One possibility is to observe neglect behavior during ADL with a structured observation scale such as the Catherine Bergego scale (CBS; Azouvi et al., 2003; Ten Brink et al., 2013). Alternatively, a multitask, such as the Mobility Assessment Course (MAC), can be administered. The design of the MAC is based on the visual search task of Verlander et al. (2000). During this task, participants have to perform a simple wayfinding task in a corridor while finding targets and reporting them. Due to higher cognitive (and motor) load, there is less room for using compensation strategies. Such a multitask might therefore assess the presence and genuine severity of neglect that patients might also demonstrate in real life. In the original study, the interrater reliability of the MAC was high (Verlander et al., 2000).

Aims of the current study were to assess the feasibility of the MAC in a rehabilitation setting and to evaluate the relation of the MAC with existing neglect tasks. First, the feasibility of administering the MAC in daily practice in a rehabilitation center was studied by evaluating the percentage of stroke patients who could complete the MAC, the total time to complete the MAC, and the percentage of targets that were visible during task administration. Second, in order to determine whether the MAC can be assessed in different corridors, the performance of healthy control subjects and the degree of crowdedness were compared between two corridors. Finally, we evaluated to what extent performance on the MAC relates to performance on standard neuropsychological neglect tasks (cancellation and line bisection) as well as observations with the CBS. As there is currently not one gold standard for the assessment of neglect, the rationale for the comparisons with existing tasks was to study what potential differences exist in overall detection rates of patients with neglect.

2. Material and method

2.1. Participants

We included patients who were admitted to inpatient rehabilitation in De Hoogstraat Rehabilitation Center. Patients with neglect were recruited via a larger randomized controlled trial (PAiR; Ten Brink, Visser-Meily, & Nijboer, 2015) #NTR3278; approved by the Medical Ethical Committee of the University Medical Centre Utrecht, #12-183/O). Patients without neglect were recruited via the neglect screening.

Inclusion criteria for the current study were: (a) clinically diagnosed symptomatic stroke (ischemic or intracerebral hemorrhagic lesion, confirmed with CT or MRI scans), first or recurrent; (b) 18–85 years of age; (c) sufficient communication and comprehension (assessed by the neuropsychologist); (d) physically and cognitively able to participate (assessed by the rehabilitation physician); and (e) unilateral lesion (in order to be able to recode the target sides as contralesional or ipsilesional). Finally, healthy controls with a comparable age distribution were recruited among relatives of the staff. Measurements took place at three locations, from May to November 2011, December 2013 to July 2015, and August 2015 to August 2016. All participants gave written informed consent. The experiment was performed in accordance with the Declaration of Helsinki.

2.2. Procedure and tasks

We reviewed the patient's medical record and captured demographic and clinical characteristics. All patients were screened for neglect (with a shape cancellation task, a line bisection task and the CBS) as

usual care within the first two weeks after admission to the rehabilitation center if their condition permitted testing (referred to as "Session 1"). This neglect screening took about 45 min. Approximately two weeks later the MAC and shape cancellation were administered for research purposes within a 30-min session (referred to as "Session 2"). Additionally, neglect patients (recruited via the PAiR study) were also tested with the line bisection, and observations were again obtained with the CBS during Session 2 (Figure 1).

2.2.1. Medical record

Education level was assessed using seven categories of a Dutch classification system, according to Verhage, 1 being the lowest (less than primary school) and 7 being the highest (academic degree) (Verhage, 1964). These levels were converted into three categories: low (Verhage 1–4), average (Verhage 5), and high (Verhage 6–7).

Global cognitive functioning was screened with either the Mini-Mental State Examination (MMSE; Folstein, Folstein, & McHugh, 1975) or the Montreal Cognitive Assessment (MoCA; Nasreddine et al., 2005). Both tests globally assess cognitive functioning, including memory, visuospatial abilities, executive functions, attention, language, and orientation in time and place. Scores range from 0 (no items right) up to 30 (all items right). For the first half of included patients, MMSE scores were obtained rather than MoCA scores due to hospitals' protocol changes. We converted MMSE scores into MoCA scores in order to create a single, pooled MoCA score. We applied the following formula: MoCA = (1.124 × MMSE) − 8.165 (Solomon et al., 2014).

Communication skills were determined with the "Stichting Afasie Nederland" test (SAN; Deelman, Koning-Haanstra, Liebrand, & van den Burg, 1981), an observation scale for language communication. Scores range from 1 (no communication through language possible) to 7 (speech and understanding of language are unimpaired).

Muscle strength was measured by the Motricity Index (Collin & Wade, 1990), a short 3-item task to assess the loss of strength in a limb. Scores range from 0 (no activity, paralysis) up to 33 (maximum normal muscle force) for each extremity. In the case of 99 points, one point is added to reach a total score of 100. The Motricity Index was assessed for both the upper and the lower extremity.

Independence in ADL was assessed using the Barthel Index (Collin, Wade, Davies, & Horne, 1988), which measures the extent to which stroke patients can function independently in their ADL. Scores range from 0 (completely dependent) up to 20 (completely independent).

2.2.2. Mobility Assessment Course

The MAC was administered in two buildings, in three corridors (Figure 2). There was no reception or main entrance in the corridors; however, therapists, patients, and visitors could enter the corridors.

Along the corridors, 24 targets (yellow, 10 × 10 cm; Figure 3) were attached to the walls, 12 on each side. As in the study of Verlander et al. (2000), targets in Corridors 1 and 2 were obstructed from view until the participant approached the target. Active search was necessary for identification. This was obtained by positioning targets next to a protruding object, such as a painting or a door. In Corridor 3, the walls were flat.

Targets were located at three different heights (4 low: 40–85 cm; 4 mid-height: 85–125 cm; 4 high: 125–165 cm). For patients who were seated in a wheelchair, targets were located at two heights (4 low: 40–85; 8 mid-height: 85–125 cm). For each corridor, three conditions were used, in which the height of the targets was varied per target location. Conditions were randomized across participants. At every turn, an arrow was attached (black on a light yellow background, A4 size; Figure 3).

Participants were instructed to walk or drive independently at a leisurely pace, without stopping or turning back. Meanwhile, participants had to point out the targets (Figure 4). Sample targets were shown during the instructions. It was emphasized that there was no
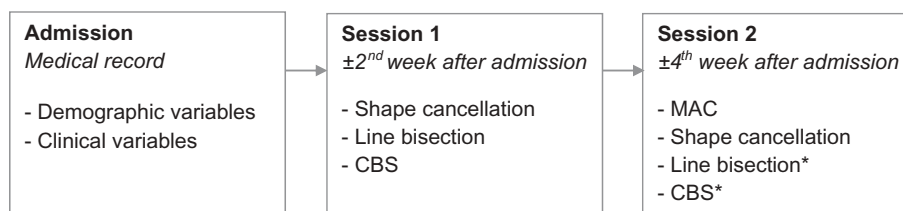

Admission *Medical record* - Demographic variables - Clinical variables	→	Session 1 *±2nd week after admission* - Shape cancellation - Line bisection - CBS	→	Session 2 *±4th week after admission* - MAC - Shape cancellation - Line bisection* - CBS*

Figure 1. Schematic overview of data collection per session. * = The task was administered only to patients who participated in the randomized controlled trial.
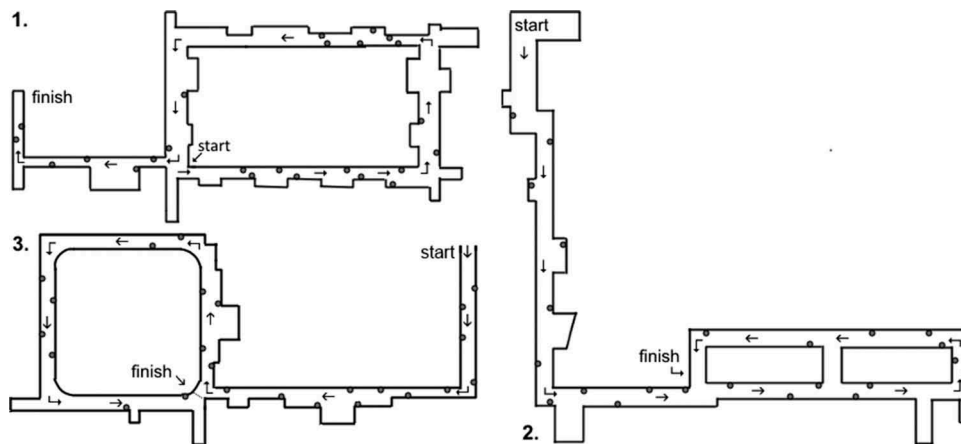
Figure 2. Map of the Mobility Assessment Course in the three corridors.

Figure 3. Arrow (left) and target (right). To view a color version of this figure, please see the online issue of the Journal.
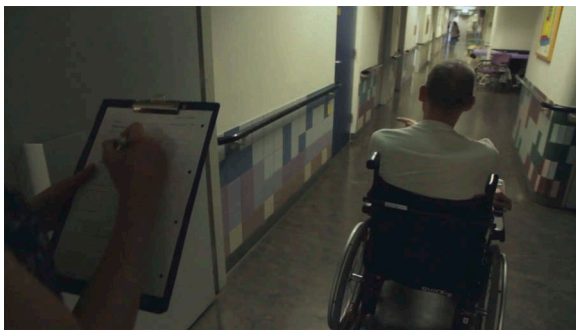

Figure 4. Assessment of the MAC in a patient with neglect. To view a color version of this figure, please see the online issue of the Journal.

time limit, and finding all targets was the main goal. Because patients were required to actively move (i.e., no assistance was offered during assessment, unless potential precarious situations were to occur), the experimental setting can be considered multitasking.

The following components were scored: number of omissions (left and right separately), the number of collisions, the number of corrections when someone took the wrong direction, the task duration (in minutes), and the number of people, ranging from 1 (empty) to 4 (over five groups of people).

When a target location was not visible during the task—for example, due to obstruction by a person or object—this target was not included in the computation of the total amount of omissions. The number of omissions was divided by the number of visible targets and was multiplied by the maximum amount of targets [e.g., $(4/11) \times 12$]. The asymmetry score was computed as the absolute difference between the number of omissions on the left and the right.

2.2.3. Shape cancellation task

The shape cancellation task consisted of 54 small targets, 52 large distractors, and 23 words and letters. Patients were instructed to cancel all targets and to tell the examiner when they had completed the task. No time limit was given. The threshold for neglect was based on the performance of 28 healthy individuals. The average omission difference score plus 3 standard deviations was 1.05, resulting in a threshold of ≥ 2 (Van der Stoep et al., 2013).

2.2.4. Line bisection task

The line bisection task consisted of three horizontal lines (22° long and 0.2° thick), presented on the upper right, lower left, and in the horizontal and vertical center of a computer screen. The amount of horizontal shift between lines was 15% of the line length. The stimulus presentation was approximately 19° wide and 5.7° high. Patients were asked to mark the subjective midpoint. For each line, the threshold for neglect was based on the performance of 28 healthy subjects. The normal range, based on the average deviation plus 3 standard deviations, was −0.77 to

0.81°, −0.85 to 0.48°, and −0.89 to 0.42° for the three lines, respectively (Van der Stoep et al., 2013). A deviation above threshold (i.e., outside normal range) on ≥2 lines was used as a threshold for neglect.

2.2.5. Catherine Bergego scale

The CBS is an observation scale for neglect in ADL (Azouvi et al., 2003; Ten Brink et al., 2013). It assesses performance in personal (body parts, body surface), peripersonal (within reaching distance), and extrapersonal space (beyond reaching distance), as well as in perceptual, representational, and motor domains. For 10 items, presence and severity of neglect were scored by the nurse, resulting in a total score of 0 (never/no neglect) to 30 (always/severe neglect). Nurses were instructed to score only behavior due to neglect and not due to other deficits (e.g., motor and/or sensory deficits). A score of ≥6 was used as a threshold for neglect (Ten Brink et al., 2013).

2.3. Statistical analyses

2.3.1. Demographic and clinical characteristics

Descriptive data on age, gender, and level of education were provided for the stroke patients and healthy control subjects. Mann-Whitney tests and chi-square tests were used to compare demographic variables between the two groups. Descriptive data on clinical characteristics (i.e., time post-stroke onset, stroke history, stroke type, lesion side, MoCA, SAN, Barthel Index, and Motricity Index arm and leg) were provided for the stroke patients.

2.3.2. Feasibility

We aimed to evaluate whether the MAC can be used as a tool within the neuropsychological assessment. Therefore, we computed the percentage of patients who were able to perform the MAC and the total time patients needed to complete the MAC. Neuropsychological tasks usually do not take more than 5–10 min on average. In addition, the percentage of targets that were visible (i.e., targets that were not obstructed by persons or objects) during task administrations of all subjects was computed, in order to determine whether administering the MAC is feasible in daily practice in a rehabilitation center.

In order to determine whether scores can be compared among different corridors, the number of omissions (total, left, and right), the asymmetry score, and the degree of crowdedness were compared between Corridors 1 and 3 with Mann-Whitney tests, with data of healthy control subjects. Not enough data was available in order to statistically compare performance in Corridor 2.

2.3.3. Relation with existing neglect tasks

Patients were grouped based on the shape cancellation and line bisection task. Patients who showed neglect during Sessions 1 and 2 on either the shape cancellation or line bisection task were referred to the neglect group. Patients with neglect on either the shape cancellation or the line bisection task during Session 1, but not during Session 2, were referred to as the recovered group. Patients who did not show neglect during Session 1 were referred to the no neglect group. Differences in performance at the MAC (the total, contralesional, and ipsilesional number of omissions, asymmetry score, collisions, and corrections for direction) between patients with neglect, recovered, and without neglect as measured with neuropsychological tasks were assessed with Mann-Whitney tests.

The threshold for neglect as measured with the MAC was based on the average asymmetry score of healthy control subjects + 2.5 standard deviations. Percentages of patients with and without neglect as measured with the MAC were provided, split for patients with and without neglect based on three different tasks (shape cancellation, line bisection, and CBS).

For patients with neglect at any of the tasks (shape cancellation, line bisection, or CBS) during Session 1, Spearman correlations between the MAC scores and performance at the shape cancellation, line bisection, and CBS (all measured during Session 2) were computed. An r of .1 was considered a small, .3 a moderate, and .5 a large correlation (Field, 2005).

For all statistical comparisons and the correlations, the level of significance was set at $p = .05$.

3. Results

3.1. Demographic and clinical characteristics

In total, 113 stroke patients and 47 healthy control subjects were included (Table 1). The age of the two groups was comparable, $U = 2139.0$, $p = .053$. The distribution of gender differed between groups, with fewer men in the control group than in the patient group, $\chi^2(1) = 12.10$, $p = .001$. Furthermore, the level of education was higher in the control group than in the patient group, $\chi^2(2) = 18.53$, $p < .001$.

We tested whether differences existed regarding the number of omissions, asymmetry score, collisions, and corrections based on gender (using Mann-Whitney test) or on the level of education (using Kruskall-Wallis non-parametric ANOVA). Comparisons were made separately for the stroke patients and healthy control subjects. No significant differences were

Table 1. Demographic and clinical characteristics, percentages, medians, and interquartile ranges.

	Patients			Controls		
Outcome	N	Mdn	IQR	N	Mdn	IQR
Age (years)	113	59.67	13.70	47	56.99	13.64
Gender, % male	113	71.7		47	42.6	
Level of education	109			47		
% Low		25.7			6.4	
% Average		36.7			19.1	
% High		37.6			74.5	
Time post-stroke onset (days)	113	37.0	25.5			
Stroke history, % first	90	84.4				
Stroke type	88					
% Ischemic		77.3				
% Intracerebral hemorrhage		19.3				
% Subarachnoid hemorrhage		3.4				
Lesion side, % left	113	41.6				
MoCA (0–30)	79	22	7.43			
SAN (1–7)	89	6	2.0			
Barthel Index (0–20)	100	10	10.0			
Motricity Index arm (0–100)	88	70.5	100			
Motricity Index leg (0–100)	90	75.0	72.0			

Note. MoCA = Montreal Cognitive Assessment, SAN = Stichting Afasie Nederland.

Table 2. MAC scores, medians, and interquartile ranges of healthy control subjects, split per corridor.

	Corridor 1	Corridor 2	Corridor 3
MAC omissions	(N = 20)	(N = 3)	(N = 24)
Total (0–24)	2.0 (4.0)	2.1 (0)	0.5 (1.0)
Left (0–12)	1.0 (1.8)	2.0 (0)	0 (0)
Right (0–12)	1.5 (1.8)	1.0 (0)	0 (1.0)
Asymmetry score	1.0 (1.8)	1.0 (0)	0 (1.0)
Crowdedness (1–4)	2 (1)	2 (0)	2 (2)

Note. MAC = Mobility Assessment Course.

protruded, which was not the case in Corridor 3. The objects in Corridors 1 and 2 were therefore only visible from a short distance, whereas targets in Corridor 3 could be seen from further away. The asymmetry score did not differ between corridors, $U = 169.5$, $p = .077$. Furthermore, the level of crowdedness was comparable, $U = 223.0$, $p = .848$.

observed on any of the comparisons regarding gender within the stroke patients (all $p \geq .139$) or healthy controls (all $p \geq .245$), or regarding the level of education within the stroke patients (all $p \geq .075$) or healthy controls (all $p \geq .305$).

3.2. Feasibility

Of 113 patients, 112 patients (99.1%) could complete the task. Patients were able to move independently along the corridor. One patient (with neglect) walked with the aid of a stick, but he could not finish walking the complete route because after a few minutes he was unable to support his weight. Subsequently, we adjusted the protocol such that patients who appeared to lack sufficient strength or stamina to walk the complete route, completed the task in their wheelchair instead. The number of omissions for this patient was included in the study, corrected for the number of targets that were presented until the task was aborted.

The duration of the task ranged from 2.22 to 9.37 min, with a median duration of 4.17 min.

In Corridors 1, 2, and 3, all targets were visible during 88.5%, 88.6%, and 93.3% of task assessments, respectively. In assessments in which not all targets were visible, only 1 or 2 targets were obstructed (by a person or an object).

The total number of omissions, $U = 68.5$, $p < .001$, left, $U = 94.5$, $p < .001$, and the number of right omissions, $U = 121.5$, $p = .003$, of healthy control subjects were higher in Corridor 1 than in Corridor 3 (Table 2). It is important to note that in Corridors 1 and 2 targets were placed next to objects that

3.3. Relation with existing neglect tasks

Of all stroke patients, 37 patients showed neglect during the first and second session, 10 patients showed neglect during the first session and not during the second session, and 60 patients did not show neglect (Table 3).

The neglect patients obtained a higher number of total and contralesional omissions, and a higher asymmetry score compared to patients without neglect (total: $U = 296.5$, $p < .001$; contralesional: $U = 323.0$, $p < .001$; asymmetry: $U = 445.5$, $p < .001$), and compared to the recovered patients (total: $U = 110.0$, $p = .050$; contralesional: $U = 102.5$, $p = .031$; asymmetry: $U = 91.0$, $p = .014$). No differences were seen regarding the number of ipsilesional omissions between patients with neglect and without neglect ($U = 959.5$, $p = .229$) and between patients with neglect and the recovered patients ($U = 174.0$, $p = .763$). The recovered patients did not differ from the non-neglect

Table 3. MAC scores, medians and interquartile ranges of patients with and without neglect.

	Neglect	Recovered	No neglect
Outcome	(N = 37)	(N = 10)	(N = 60)
Lesion side left/right	2/35	5/5	35/25
Walking/wheelchair	13/24	4/6	40/20
MAC omissions			
Total (0–24)	8.0 (5.0)	4.5 (8.0)	2.0 (3.0)
Contralesional (0–12)	4.5 (8.0)	4.0 (7.0)	1.0 (2.0)
Ipsilesional (0–12)	1.0 (3.0)	1.0 (2.0)	0.0 (2.0)
Asymmetry	7.0 (7.5)	3.5 (5.3)	1.0 (1.8)
MAC collisions	0 (1)	0 (0)	0 (0)
MAC corrections	0 (1)	0 (0)	0 (0)

Note. Neglect = patients with neglect during Session 1 and Session 2. Recovered = patients with neglect during Session 1, and without neglect during Session 2. No neglect = patients without neglect during Session 1. MAC = Mobility Assessment Course.

patients for any of the omission scores (total: $U = 199.0$, $p = .086$; contralesional: $U = 190.0$, $p = .057$; ipsilesional: $U = 269.0$, $p = .573$; asymmetry: $U = 226.0$, $p = .197$).

Neglect patients collided more than did patients without neglect, $U = 841.0$, $p < .001$, but not more than the recovered patients, $U = 135.0$, $p = .069$. No difference was seen between the recovered patients and patients without neglect, $U = 290.0$, $p = .561$. Of all neglect patients, 27% bumped at least once, whereas only 3.3% of the non-neglect patients and 0% of the recovered patients bumped. As there were only little collisions, this measure provides no additional information regarding neglect (see also Jacquin-Courtois, Rode, Pisella, Boisson, & Rossetti, 2008; Verlander et al., 2000).

Finally, patients with neglect went in the wrong direction more often than did patients without neglect, $U = 818.0$, $p = .004$, and more often than did the recovered patients, $U = 126.0$, $p = .067$. Patients without neglect did not differ from recovered patients, $U = 284.0$, $p = .658$. Of patients with neglect, 40.5% had to be corrected at least once, whereas 15.0% of the non-neglect patients and 10.0% of the recovered patients had to be corrected.

The average asymmetry score of healthy control subjects was 0.75 ($SD = 0.81$). Based on this, the threshold for neglect was an asymmetry score of 2.78. Of patients with neglect on the cancellation task at both sessions, 82.8% showed neglect on the MAC (Table 4). In the recovered group this was 66.7%, whereas 9.5% of patients without neglect as measured with the shape cancellation task showed neglect on the MAC. When patients were grouped based on the line bisection, 81.0% of patients with neglect during both sessions showed neglect on the MAC. In the recovered group, 60.0% showed neglect as measured with the MAC. Of patients without neglect on the line bisection, 18.6% showed neglect on the MAC. Within the group of patients with neglect as measured with the CBS during both sessions, 70.7% showed neglect on the MAC as well, whereas this was 33.3% in the recovered group.

Only 4.0% of patients without neglect on the CBS, did show neglect on the MAC.

The number of total omissions, contralesional omissions, and the asymmetry score at the MAC showed large positive correlations with the shape cancellation and moderate positive correlations with the line bisection and CBS total score (Table 5). The CBS items "grooming," "looking toward one side," "forgetting part of body," "orienting of attention," and "colliding" showed a moderate positive relation with the total number of omissions, contralesional omissions, and asymmetry score obtained with the MAC. The items "way finding" and "finding personal belongings" showed a moderate positive relation with the total number of omissions and the contralesional omissions at the MAC. The items "adjusting clothes," "food on plate," and "mouth cleaning" were not related to performance at the MAC.

4. Discussion

Aims of the current study were to determine the feasibility of the MAC—a task that could be used as an ecologically valid multitask in the assessment of neglect —and its relation to existing neglect tasks. Administering the MAC as part of a neuropsychological assessment seems feasible, as all patients, with the exception of one (99.1%) who were able to perform standard neuropsychological assessment could also complete the MAC. In addition, the median task duration was only 4.17 min, which is comparable to the administrations of a standard neuropsychological paper-and-pencil task. Furthermore, depending on the corridor where the MAC took place, in 6.7–14.5% of all assessments a maximum of two targets was obstructed. This indicates that setting up a route with targets that are visible is possible in the corridor of a rehabilitation center.

Patients with neglect at paper-and-pencil tasks had more omissions during the MAC than did patients without neglect, indicating that there is agreement between these tasks. Nevertheless, 9.5–18.6% of patients *without* neglect as assessed with neuropsychological assessment

Table 4. Percentages of patients with neglect during the MAC, split for patients with and without neglect based on three different tasks.

	Shape cancellation (N = 112)			Line bisection (N = 90)			CBS (N = 103)		
	Neglect	Recovered	No neglect	Neglect	Recovered	No neglect	Neglect	Recovered	No neglect
MAC neglect	(N = 29)	(N = 9)	(N = 74)	(N = 21)	(N = 10)	(N = 59)	(N = 41)	(N = 12)	(N = 50)
% Neglect	82.8	66.7	9.5	81.0	60.0	18.6	70.7	33.3	4.0
% No neglect	17.2	33.3	90.5	19.0	40.0	81.4	29.3	66.7	96.0

Note. Neglect = patients with neglect during Session 1 and Session 2. Recovered = patients with neglect during Session 1, and without neglect during Session 2. No neglect = patients without neglect during Session 1. CBS = Catherine Bergego scale, MAC = Mobility Assessment Course.

Table 5. Spearman correlations between the MAC, shape cancellation, line bisection, and CBS.

| Outcome | N | MAC omissions | | | |
		Total	Contralesional	Ipsilesional	Asymmetry
Shape cancellation, asymmetry	69	.53**	.52**	.04	.56**
Line bisection, deviation	57	.38**	.39*	.06	.39**
CBS total score	54	.42**	.45**	−.01	.48**
Grooming	50	.28*	.32*	−.09	.35*
Adjusting clothes	41	.15	.14	−.01	.25
Food on plate	49	.07	.13	−.15	.22
Mouth cleaning	48	.18	.21	−.02	.27
Looking toward one side	47	.39**	.38**	.18	.33*
Forgetting part of body	45	.31*	.34*	.03	.30*
Orienting of attention	49	.34*	.38**	−.03	.41**
Colliding	51	.49**	.51**	.12	.46**
Way finding	47	.33*	.30*	.17	.23
Finding personal belongings	48	.35*	.33*	.16	.23

Note. CBS = Catherine Bergego scale, MAC = Mobility Assessment Course.
*$p \le .05$; **$p \le .01$.

showed neglect as measured with the MAC. This strengthens the view that clinical diagnosis of neglect requires more than a significant difference on one test, preferably across tests of varying dynamics and complexity. For some patients, the reverse pattern was seen: 17.2–19.0% showed neglect as measured with neuropsychological assessment, but *not* at the MAC. The variation in percentages of patients with neglect across tasks could relate to the heterogeneity of the neglect syndrome. One possible explanation for these seemingly contradictory findings might lie in the level of arousal needed to perform those different tasks. A subset of patients with neglect is known to have severe problems in maintaining arousal during tasks. It might be that for some patients the MAC as a multitask—encompassing multisensory stimulation, for example (Tinga et al., 2015)—maintains their level of arousal more than do the neuropsychological paper-and-pencil neglect tasks. In other patients, however, the lateralized attention deficit as the core of the neglect syndrome may appear aggravated due to the complex and dynamic nature of the tasks. To exactly pinpoint the underlying mechanisms in (individual) patients with neglect is still difficult. With respect to the MAC and its relation to other neglect tasks, the use of the MAC would—at this stage—be a supplementary one.

Additionally, the results of the "recovered" group (i.e., patients who only showed neglect during the first session but not during the second session) are remarkable, as 60.0–66.7% of patients in this group showed neglect as measured with the MAC, whereas these patients did not show neglect on the second session with the neuropsychological neglect tasks.

These results fit the clinical observations that neuropsychological assessment is not always sensitive enough to detect neglect, especially when there is no time limit, when stimuli are static, and when the attentional load is low (Azouvi, 2016; Huisman et al., 2013; Ten Brink et al., 2013). The MAC may detect neglect in "recovered" patients due to its complex and dynamic nature in which the lateralized attention deficit could manifest. There is ample evidence that "recovered" patients can show large attentional asymmetries while dual-tasking (e.g., Bartolomeo, 1997; Blini et al., 2016; Bonato, 2015; Bonato, Priftis, Umiltà, & Zorzi, 2013; van Kessel et al., 2013), suggesting that at least some of the patients within this group are most likely not actually recovered. The MAC appears to be an ecologically valid, dynamic multitask that is quite easy to implement in *clinical practice*.

Severity of neglect as measured with the MAC related to neglect severity as measured with standard neglect tasks. Specifically, a strong positive relation was seen between asymmetry scores obtained at the MAC and asymmetry scores obtained at the shape cancellation task. Visual search is the key aspect in both tasks, and eye movements are most probably the common feature—and head movements, to a somewhat lower extent—in both tasks. The spatial bias is in both tasks the most important outcome measure. Such a strong positive relation is therefore not surprising. There is one aspect that might be measured with the MAC that cannot be easily measured with cancellation tasks, and that is region specificity of neglect (but see also below). As double dissociations exist between neglect in peripersonal and extrapersonal space, this could explain why some patients showed neglect on one task and not on the other (Berti & Frassinetti, 2000; Van der Stoep et al., 2013).

A moderate positive relation was found between the performance on the MAC and the magnitude of displacement of the bisection mark. Given the differences in nature of both tasks, this is also an interesting finding. During the line bisection task patients have to estimate the middle of a line. A lack of attention to one side of the line results in a deviation of the estimated middle toward to opposite side. Contrary to the MAC and the cancellation task, the line bisection task depends primarily on the perceptual estimation of a single stimulus without the competition of other stimuli (Ferber & Karnath, 2001). Perceptual estimations are also components of the MAC, albeit to a much lesser extent: such deviations during an ecologically valid tasks in which observations are the secondary most important outcome measure are much more difficult to scrutinize. When perceptual estimations in

neglect are the focus of research or assessment, one could make better use of a more fine-grained measure.

Another complementary tool for assessment of neglect in ADL is the CBS. In prior studies, the relation between the CBS and paper-and-pencil tasks was assessed, and the CBS detected about 10% of patients who did not show neglect at standard neuropsychological assessment, and vice versa (Azouvi et al., 2003; Ten Brink et al., 2013). In the current study, more patients were diagnosed with neglect based on the CBS (40%) compared to neuropsychological assessment (23–26%). In addition, only 4.0% of patients who did not show neglect based on the CBS were diagnosed with neglect based on their performance on the MAC. This might suggest that adding the CBS to a standard neglect battery would suffice. However, observed neglect behavior in ADL as measured with the CBS showed only a moderate positive relation with performance at the MAC. Similarities with the MAC are that the CBS also includes the dynamic character of daily life, and observations can be made while patients have to attend to different regions of space (Nijboer, Ten Brink, Kouwenhoven, & Visser-Meily, 2014). However, there are also important differences between the MAC and CBS that would warrant the use of both instruments. First, the CBS lacks explicit multitasking and measures of divided attention. In addition, a larger variety of situations and constructs are included in the CBS compared to the MAC (Goedert et al., 2012). At item level, there were significantly positive relations between performance on the MAC and all CBS items, except "adjusting clothes," "food on plate," and "mouth cleaning." Given the dynamic (continuous movements) nature of the MAC in combination with the wayfinding and object-finding elements, it is very likely that both peripersonal and extrapersonal neglect could be detected. As people move forward through a corridor, elements that appear in extrapersonal space slowly come nearer. Observations are in the current form of the MAC the only way to "measure" when and where elements are noticed and access awareness. This is not a very neat measure, however, to differentiate between region-specific types of neglect. Notwithstanding its imprecise indication of attended elements in different regions of space, the MAC in its current form is likely to give extra observational information on attention processing in different regions of space. When one wants to have more precise measures of access awareness of objects in different regions of space, virtual reality tasks can be used in which eye tracking can give very detailed information on the when and where of object awareness.

Moving independently and obtaining a good spatial orientation are important goals in clinical rehabilitation, as they are important for participation. Nevertheless, these aspects are rarely considered in the diagnosis of neglect. The MAC provides a semi-structured framework in order to assess neglect. In general, healthy control subjects perform well and the difference in performance between corridors is small (asymmetry scores of 0.96 and 0.55). In addition to quantitative information, observations can be made during the MAC. More specifically: the position of the head or the occurrence of head movements, the position in the corridor and the occurrence of collisions can be observed. The task can also be used to practice visual scanning or in order to provide insight to the patient. With the latter aim, the task can be assessed multiple times, for example in reversed order, so that the patient becomes aware of the number of targets that were missed during the first assessment. It should be emphasized that, as with neuropsychological assessment, the complete profile of performances at different tasks is important for the diagnosis of neglect, in combination with qualitative observations. For example, a patient with left-sided neglect could miss targets on the right side, due to overcompensation or by remaining at the right side of the corridor, and observations during the MAC are necessary for adequate interpretation of the outcomes.

Several other tasks are developed to assess neglect in a dynamic or ecologically valid manner. Detection tasks in which reaction times of responses are measured, combined with other tasks (such as discrimination tasks), are more demanding and more sensitive to the lateralized attentional deficit compared to static tasks (Bonato et al., 2010; Russell, Malhotra, Husain, & Malhotra, 2004). Such dual-tasks—especially in a daily setting or as a daily activity to enlarge the external validity—add to the current diagnostics (Marshall, Grinnell, Heisel, Newall, & Hunt, 1997; van Kessel et al., 2013).

4.1. Limitations

One limitation is that tasks in which a daily life setting is used can never be completely standardized across settings. First, corridor features—for example, the length of the route, the number of turns, the color of the walls, and the possibility to place targets behind protruding parts—differ between institutions. Second, other activities that take place in the corridor cannot be controlled for, and thus the crowdedness can vary per

assessment and is likely to have an impact on the overall performance of patients. Therefore, it is crucial to explore each corridor and investigate performance in a representative group of healthy control subjects, as we did in the current study. Still, one does not have control over activities in a corridor during assessment. Neglect assessment using the MAC in a somewhat secluded corridor might be an option in some, but not all institutions. For better control of activities in such daily life settings, virtual reality simulations may be used in the future, allowing patients to perform a cognitive multitask while interacting with the fully controlled environment.

In addition, when tasks are assessed in daily life situations in which active movement of the patient is required, which is the case during the MAC and the CBS, effects of motor impairments could affect performance. For example, loss of strength in one arm could lead to an asymmetric wheelchair driving pattern during the MAC or adjusting clothes as one of the items of the CBS. Although staff was trained to score deficient behavior with both the CBS and the MAC, the interaction between neglect and motor deficits is a complex one, and observations leave room for different interpretations. In our study, only one neuropsychologist (MAC) or one nurse (CBS) observed each patient. An improvement might be to always have two persons observe and rate patient behavior, yet this might be difficult to accomplish in a clinical setting.

Potentially, other disorders of visual perception, such as scotoma and hemianopia, might also result in omissions at the MAC (Verlander et al., 2000). Observations of the neuropsychologists during the MAC are therefore of utmost importance, as the behavioral consequences—also as the result of awareness of the disorder and the ability to (spontaneously) compensate—of hemianopia versus neglect are quite substantial, especially in the subacute phase post stroke onset. In addition, it is important to always screen for scotoma and hemianopia, either with neurological and/or behavioral tasks and/or with MRI scans.

5. Conclusions

The MAC is a visual search–multitask during which quantitative and qualitative data can be collected. Due to higher cognitive and motor load and the dynamic character of the task, there is less room for using compensation strategies. A structured observation, which can be obtained during the MAC, provides relevant information in addition to quantitative data. Administering the MAC seems feasible in stroke patients in a rehabilitation setting. There is a moderate

to high agreement between the MAC and existing paper-and-pencil tasks for neglect. However, some stroke patients perform normally on paper-and-pencil tasks, but they show neglect as measured with the MAC, and vice versa. The variation in percentages of patients with neglect across tasks could relate to the heterogeneity of the neglect syndrome. To conclude, the MAC could be administered along with paper-and-pencil tasks in order to assess the existence of neglect and neglect severity in a dynamic way.

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