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Citation

Bosma, M. S., Nijboer, T. C. W., Caljouw, M. A. A., & Achterberg, W. P. (2020). Impact of visuospatial neglect post-stroke on daily activities, participation and informal caregiver burden: a systematic review. *Annals Of Physical And Rehabilitation Medicine*, *63*(4), 344-358. doi:10.1016/j.rehab.2019.05.006

Version:	Publisher's Version
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Downloaded from:	https://hdl.handle.net/1887/3181319

Note: To cite this publication please use the final published version (if applicable).

Annals of Physical and Rehabilitation Medicine 63 (2020) 344–358

Available online at ScienceDirect www.sciencedirect.com

Elsevier Masson France EM|consulte www.em-consulte.com

Review

Impact of visuospatial neglect post-stroke on daily activities, participation and informal caregiver burden: A systematic review

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ARTICLE INFO

Article history:
Received 8 February 2019
Accepted 8 May 2019

Keywords:
Stroke
Visuospatial neglect
Unilateral neglect
Activities of daily living
Participation
Caregiver burden

ABSTRACT

Objectives: Visuospatial neglect (VSN) is a common cognitive disorder after stroke. The primary aim of this systematic review was to provide an overview of the impact of VSN in 3 aspects: (1) activities of daily living (ADL), (2) participation, and (3) caregiver burden. The second aim was to investigate the differences in studies focusing on populations with mean age < 65 versus ≥ 65 years.
Methods: PubMed, EMBASE, Web of Science, Cochrane Library, Emcare, PsychINFO, Academic Search Premier and CENTRAL were searched systematically. Quality was assessed with the Mixed Methods Appraisal Tool.
Results: Of the 115 included studies, 104 provided outcomes on ADL, 15 on participation (4 studies with mean age ≥ 65), and 2 on caregiver burden (1 study with mean age ≥ 65). Quality assessment yielded scores ranging from 0 to 100%. VSN had a negative impact on ADL (i.e., independence during ADL and performance in self-care, household tasks, reading, writing, walking, wheelchair navigation) and participation (i.e., driving, community mobility, orientation, work). The impact of VSN on fulfilling social roles was unclear. VSN had a negative effect on caregiver burden. We found no clear age-related differences.
Conclusions and implications: VSN has a negative impact not only on patients' independence but particularly on the performance of ADL. Despite the far fewer studies of VSN as compared with ADL, VSN also seems to hamper participation and increase caregiver burden, but further research is needed. Because of the large impact, VSN should be systematically and carefully assessed during rehabilitation. A considerable number of different instruments were used to diagnose VSN. Diagnosing VSN at more than one level [function (i.e., pen-and-paper test), activities, and participation] is strongly recommended. Consensus is needed on how to assess VSN and its negative impact for research and rehabilitation practice.
Systematic review Registration No.: PROSPERPO Registration No. CRD42018087483.
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1. Introduction

Visuospatial neglect (VSN) is a common cognitive disorder after stroke. Patients with VSN have problems reporting and responding or orienting to visual stimuli in the contralesional hemispace that cannot be attributed to sensory or motor impairments [1]. Estimates of the incidence of VSN after stroke differ, ranging from 20% to 82%, largely dependent on the patient sample, time post-stroke onset, and number and types of tests used for assessment [2]. VSN can easily become a chronic disorder; half of the stroke patients with VSN still have VSN at 1 year after stroke onset [3].

The impact of VSN can be far-reaching for patient's everyday life. Stroke patients with VSN show slower recovery and less recovery in activities of daily living (ADL) as compared with non-VSN patients [4–8] and remain more dependent on their environment during (basic) ADL [4]. Considering this negative impact, VSN may also have severe consequences for informal caregivers (hereafter called caregivers) of VSN patients.

Previous reviews have mainly focused on the consequences of VSN for body function and body structure [9,10] or on the impact of

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https://doi.org/10.1016/j.rehab.2019.05.006
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VSN mainly measured by independence during ADL [5,8]. The aim of this review was to provide a systematic overview of the impact of VSN on (1) ADL, (2) participation, and (3) informal caregiver burden. In contrast to previous studies, the present review focuses on the quality of ADL and participation. We include all types of study designs, not just randomized controlled trials (RCTs) or large cohort studies, to provide a wider overview of the current situation. As well, although stroke is common and VSN occurs with increasing frequency and increasing severity in the geriatric population [11], many studies address younger populations. Therefore, to gain more insight into potential differences by age, the second aim was to provide a descriptive overview of differences between studies (i.e., amount of data available, outcomes examined) including younger versus older patients (mean age < 65 vs. ≥ 65 years).

2. Materials and methods

2.1. Protocol and registration

The protocol for this systematic review was pre-registered in the PROSPERPO Database (registration no. CRD42018087483). This review followed the standard guidelines of Preferred Reporting items for Systematic Reviews and Meta-Analyses (PRISMA) [12].

2.2. Search strategy and article selection

We conducted a systematic literature search on May 1, 2018 in the electronic databases PubMed, EMBASE, Web of Science, Cochrane Library, Emcare, PsychINFO, Academic Search Premier and CENTRAL by using the terms visuospatial neglect, stroke, activity, participation and caregiver burden (Appendix). We had no restrictions on publication date or research design. After removing duplicates, we excluded study reports that were:

- not in English;
- not related to humans;
- not original research (e.g., an editorial or review);
- intervention studies;
- focusing on other levels than activity or participation;
- not related to stroke;
- not related to VSN;
- not describing a relation between VSN and outcome measure (non-relation);
- not available in full text.

In case of ambiguity in article selection with respect to the exclusion criteria related to activity and participation, activity and participation level were defined according to the International Classification of functioning, Disability and Health Framework (ICF) of the World Health Organization [13]. Activity was considered the execution of a task or action by an individual [14]. Only ADL within this framework were included (e.g., self-care and household task). Reading was included only when it involved more than single words. Reaching was included only if it was goal-directed grabbing or holding; otherwise it was considered a "function" according to the ICF. Virtual reality (VR) was included when it was used to measure an activity in daily life (e.g., walking) in a protected environment. According to the ICF, participation is defined as involvement in a life situation (e.g., driving) [14].

The first author (MB) screened titles and abstracts; in case of uncertainty, the second author (TN) was consulted to reach consensus. Among the included abstracts, full-text articles (when available) were screened. Two reviewers (MB and TN) independently assessed the full-text articles. The reviewers' selection and arguments were compared, and any differences regarding the inclusion of an article were discussed to reach consensus.

2.3. Data extraction and analyses

After the final selection, data were extracted by the first author (MB). In case of uncertainty, the second author (TN) was consulted. The following study characteristics were extracted: authors, year, study design, number of patients, proportion of VSN, mean age, mean time post-stroke onset, setting, country, diagnostic instrument used to assess VSN, outcome measures in ADL, participation or caregiver burden, main findings in (sub)categories of ADL and participation (e.g., self-care and household tasks by ADL, or driving by participation), and total methodological quality score. The primary outcome was the impact of VSN on ADL, participation and caregiver burden. The secondary outcome was the overview related to age (mean population age < 65 vs. ≥ 65 years). The widespread differences in study characteristics precluded the possibility to directly compare results; therefore, a meta-analysis was not possible. A narrative synthesis of the findings is presented.

2.4. Quality assessment

The Mixed Methods Appraisal Tool (MMAT v2011) was used to assess the methodological quality of studies [15]. The MMAT was designed for appraising complex systematic literature reviews that include domains of qualitative, quantitative and mixed-methods studies. Scores on the MMAT range from 0% (no criteria met) to 100% (all criteria met). Each study included in this review was defined by a research design of the MMAT and assessed within its methodological domain [15]. The included studies were assessed by the first 2 authors separately (MB and TN), then discussed in detail. Any disagreement was discussed until consensus was reached. If no consensus was reached, advice was sought from the third author (MC).

3. Results

3.1. Study selection

The search yielded 4,669 citations. After removing duplicates, we screened 1,931 articles on the basis of the title and abstract and excluded 1,657. The 274 remaining studies were analyzed in full text. Finally, reports for 115 studies met the inclusion criteria and were included in this review (Fig. 1).

3.2. Study characteristics

Study characteristics are presented in Tables 1–3 based on ADL, participation, and caregiver burden. The studies had considerable diversity regarding study design; number of included patients; proportion of VSN; mean age of participants; mean time post-stroke onset; setting; diagnostic instrument used to assess the presence of VSN; outcome measure in ADL, participation or caregiver burden; categories of ADL; and participation in various activities.

Most studies were performed in Europe ($n = 51$); 10 were from the United States/Canada, 9 from Asia, 5 from Oceania, and 1 study covered both Europe and North America. For 39 reports, the study location of inclusion and assessment were not specified. Most studies were conducted in a rehabilitation setting ($n = 50$) and 10 were community-based. In another 35 studies, patients were selected from a hospital setting. Not all reports differentiated between in/outpatients. In 4 studies, patients were recruited from a Center for Evaluation of Fitness to-Drive and Car Adaptations [16–19]. The settings of 16 studies were unclear or not specified.

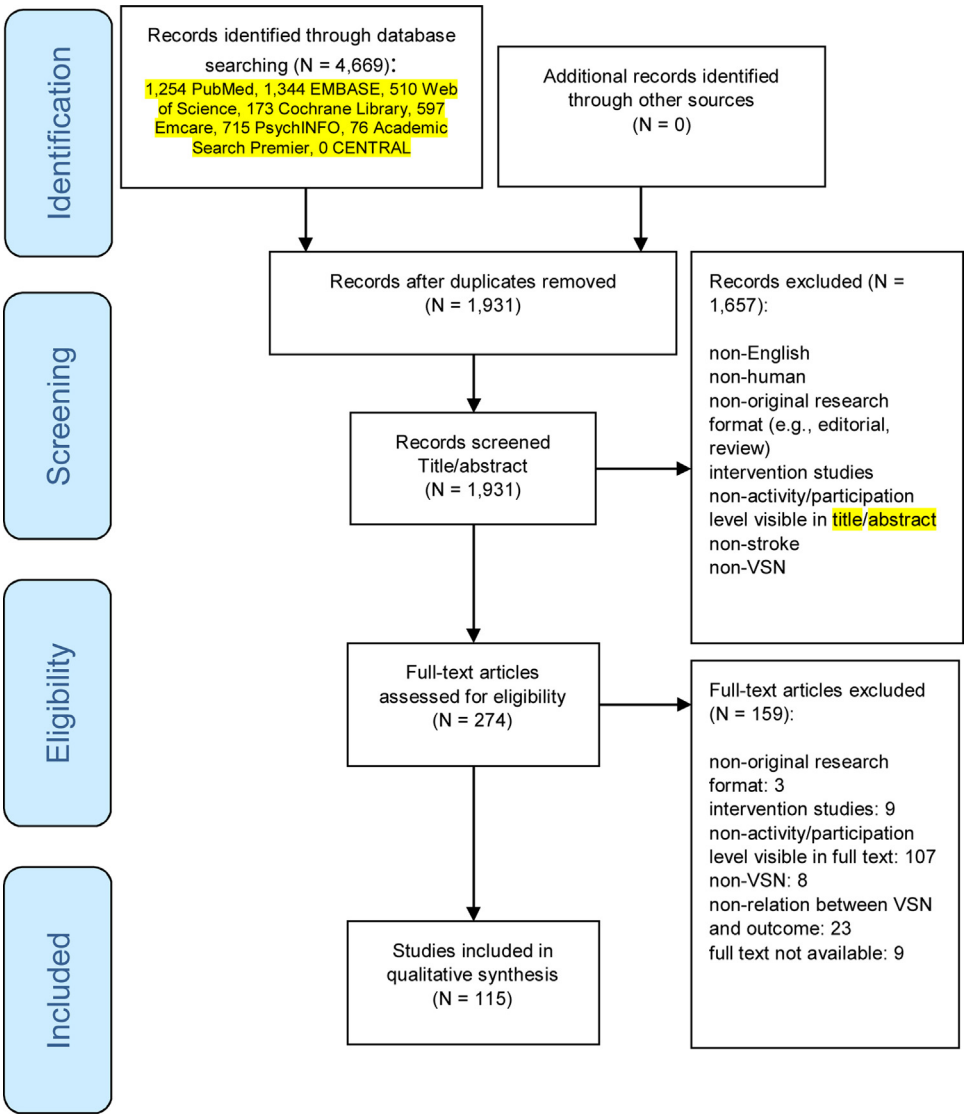

Fig. 1. Flowchart of study selection.

All included studies used measurement tools to first assess VSN within the study population. These tools were used independent of the outcome measures. Tables 1–3, column 8 (VSN tests), shows that many different tests were used to diagnose VSN. As a diagnostic measurement for VSN, a pen-and-paper test was used in 98 studies. A cancellation task ($n = 92$) was mostly used, either in isolation or in a test battery (e.g., the Behavioral Inattention Test [BIT]). The line bisection task was used 57 times, also in isolation or in a test battery. For assessing VSN during ADL, tests used were the Catherine Bergego Scale (CBS) ($n = 11$), Kessler Foundation Neglect Assessment Process ($n = 4$) and Dublin Extrapersonal Neglect Assessment ($n = 1$). Most studies used more than one (diagnostic) assessment to identify VSN, independent of the outcome measure. In 13 studies, a single test was used (test battery such as BIT excluded). The (subtest of the) BIT was used in 36 studies.

Mean age of the population ranged from 50 to 84 years. We distinguished between study populations with mean age $\geq$ 65 years ($n = 51$ studies) and $<$ 65 years ($n = 55$ studies). Nine reports did not include the mean age or the age could not be calculated from the data available. Overall, 104 reports provided data on ADL, 15 on participation level, and 2 on caregiver burden. These outcomes could be studied in isolation or combined.

3.3. Quality assessment

An overview of the quality assessment (based on MMAT total scores) is presented in Tables 1–3 (last column). We found a large variation in research designs and methodological quality. Total MMAT scores for the 115 included studies ranged from 0% ($n = 2$) to 100% ($n = 34$).

Most studies had a "Quantitative non-randomized design" ($n = 88$). Within this category, 45 cohort studies, 22 case–control studies, and 21 cross-sectional studies were specified. Their quality ranged from 0 to 100%. Of the 88 studies, 63 scored $\geq$ 75%, with 26 scoring 100%. In this category, the quality of the studies scoring $<$ 100% was limited in terms of recruitment of participants, appropriate measurements, comparable groups, and complete outcome data.

In the MMAT category "Quantitative descriptive studies", 15 studies were specified: 9 incidence or prevalence studies, 5 case series, and 1 case report. The quality ranged from 25% to 100%. Of the 15 studies, 12 scored $\geq$ 75%, with 6 scoring 100%. In this category, the quality of the studies scoring $<$ 100% was limited in terms of sampling strategy, representative population, appropriate measurement and response rate.

Table 1
Overview of studies: activities of daily living.

Study, year	Design	Number of patients (hemisphere of lesion)	VSN %	Age, mean (SD), years	Time post-stroke onset, mean (SD)	Setting, country	VSN tests	Outcome measures			Main findings		
								Independence	ADL	Participation	Category	Subcategory	MMAT score %
Appelros et al., 2002	Incidence/prevalence	270 stroke (126 RH, 146 LH 146, 7 unknown or BL)	23%	76.6	1–4 days up to 1 month	Community, Sweden	r-BIT, BTT	Katz ADL Index	–	–	ADL	Independence	100
Appelros et al., 2003a	Cohort	377 stroke	23%	77	Baseline and 1 year later	Hospital, Sweden	r-BIT, BTT	Katz ADL Index	–	–	ADL	Independence	75
Appelros et al., 2003b	Case series	131 stroke	Unknown	Unknown	Unknown	Community, Sweden	r-BIT, BTT	Katz ADL Index	Observation	Observation	ADL and Participation	ADL: self-care and household tasks, walking and wheelchair navigation, participation: community mobility and orientation	100
Appelros et al., 2004	Cohort	37 left UN	100%	74	2–4 weeks, at 6 months and at 1 year.	Rehabilitation, Sweden	BIT	FIM	–	–	ADL	Independence	50
Aravind and Lamontagne, 2014	Case series	12 VSN	100%	60.7	3-90 months	Rehabilitation, Canada	MVPT, Star cancelation test, Bells test, line bisection	–	Trail making B, walking capacity VR	–	ADL	Walking and wheelchair navigation (VR)	75
Aravind and Lamontagne, 2017a	Case–control	26 RH stroke	50%	60.8 (6.5) VSN−, 59.8 (7.7) VSN+	11.8 (5.1) months VSN−, 10.5 (4.6) months VSN+	Rehabilitation, Canada	Bells test, Line Bisection test, Apples test	–	VR negotiate moving obstacles while walking	–	ADL	Walking and wheelchair navigation (VR)	100
Aravind and Lamontagne, 2017b	Case–control	26 RH stroke	50%	60.3	1–20 months	Unknown, Canada	MVPT, Letter Cancellation Test or Bells Test	–	VR avoiding obstacles	–	ADL	Walking and wheelchair navigation (VR)	100
Azouvi et al., 2002	Incidence/prevalence	206 RH stroke	85.9%	55.9 (15.3)	11.1 (13.8) weeks	rehabilitation, France and Belgium	gaze orientation, pen and paper tests	–	CBS	–	ADL	Self-care and household tasks	75
Barker-Collo, 2010a	Case-control	43 stroke (18 RH)	Unknown	68.51	18.6 (7.6) days	Hospital, New Zealand	Bells test, IVA-CPT, Trail-Making Test A/B	BI, MRS	–	–	ADL	Independence	100
Barker-Collo et al., 2010b	Incidence/prevalence	94 stroke	36,5%	68.22 (15.65)	17.9 (10.05)	Hospital, New Zealand	Bells test, IVA-CPT, Trail-Making Test A/B	BI, MRS	LHS	–	ADL	Independence	75
Beschin and Robertson, 1997	Case-control	31 RH, 13 LH, 17 controls	*N* = 17	65.1 RH N+, 64.4 RH N−, 63.2 LH, 60.9 controls	3.1 RH N+, 2.7 RH N−, 2.8 LH months	Unknown, Unknown	albert's test, line and letter cancellation, Wundt-Jastrow illusion, drawing from memory, copying shapes	–	Comb and razor	–	ADL	Self-care and household tasks	25
Beschin et al., 2014	Case-control	30 RH stroke with VSN	100%	63.1 (12.7)	75 (118) days	Unknown, Unknown	Cancellation tasks (Stars, Letters or Circles) and drawing tasks	–	Single word and prose reading, text on 1and 2 columns	–	ADL	Reading and writing	75
Bienkiewicz et al., 2015	Case-control	38 LH, 17 RH and 12 controls	Unknown	58.9 (12) LH, 61 (12) RH, 55.8 (13.4) healthy	99.4 LH, 127.3 RH	Hospital, Germany	BCoS	–	tea making and down filling task	–	ADL	Self-care and household tasks	75
Bonato et al., 2012	Case report	1 RH (and 5 patients RH)	100%	63	5 days	Hospital, Unknown	BIT subtests	FIM, BI	CBS	Questionnaire, interview and observation	ADL	Self-care and household tasks, walking and wheelchair navigation and reading and writing	50
Bowen et al., 2005	Case-control	42 RH stroke	*N* = 7	73	42 days	Hospital, England	Star cancellation, modified BTT	–	key removing, grocery naming, face washing, tray wiping	–	ADL	Self-care and household tasks	75
Brown and Powell, 2017	Case study	2 Stroke with VSN	100%	52 and 62	15 and 44 days	Rehabilitation, Unknown	BIT, star cancellation, item location task	FIM	BIT ADL scale, CBS, wheelchair collision	–	ADL	Self-care and household tasks	75
Buxbaum et al., 2008	Incidence/prevalence	9 RH stroke	Unknown	57.3 (14.6)	31.9 (23.1) months	Unknown, Unknown	letter and bell cancellation, line Bisection, picture scanning, menu Reading	–	VWNT (VR)	–	ADL	walking and wheelchair navigation (VR)	25
Buxbaum et al., 2012	Case-control	70 RH stroke, 10 controls	Unknown	59.5 range 21–79 RH, 61.6 range 34–78 controls	29 months, range 5–87	Rehabilitation, United States	letter and bell cancellation, line bisection, RWN	–	VRLAT (VR)	–	ADL	Walking and wheelchair navigation (VR)	100
Cassidy et al., 1998	Cohort	250 stroke (66 RH)	40,9%	76, range 39–95	Median 3 days	Hospital, Scotland	BIT	BI	–	–	ADL	Independence	75

Table 1 (*Continued*)

Study, year	Design	Number of patients (hemisphere of lesion)	VSN %	Age, mean (SD), years	Time post-stroke onset, mean (SD)	Setting, country	VSN tests	Outcome measures			Main findings		
								Independence	ADL	Participation	Category	Subcategory	MMAT score %
Cermak and Hausser, 1989	Case-control	80 stroke (26 LH, 54 RH, 50 controls)	LH 15%, RH 48%	Stroke: 54.6 LH, 57.7RH, 58 controls	Unknown	Rehabilitation, Great Britain	Conventional subtest BIT	-	Behavioural subtest BIT	–	ADL	Self-care and household tasks	50
Chen et al., 2015a	Cohort	121 stroke (36 LH, 85 RH)	*N* = 82	70	6 days	Rehabilitation, Unknown	KF-NAP	FIM	–	–	ADL	Independence	100
Chen et al., 2015b	Cohort	108 stroke (34 LH, 74 RH)	68.5%	70.1	6 days	Rehabilitation, Unknown	KF-NAP	FIM, BI	–	–	ADL	Independence	100
Chen-Sea, 2001	Cross-sectional	46 RH stroke	7 extra-personal, 2 personal, and 11 both	59.2	102.66 days	Hospital, Taiwan	Draw-A-Man-Test, Random Chinese Word Cancellation Test	Klein-Bell ADL Scale	–	–	ADL	Independence	75
Cherney and Halper, 2001	Cohort	54 RH stroke	Unknown	65.94 (13.21)	35.40 (23.8) days	Unknown, Unknown	Conventional subtest BIT	–	Behavioral subtest BIT	–	ADL	Self-care and household tasks	25
Cherney et al., 2001	Cohort	52 RH stroke	Unknown	66.19 (13.46)	33.13 (68.40) days	Rehabilitation, Unknown	BIT	FIM	Reading and writing items of the RIF-CAS	–	ADL	Independence and reading and writing	50
Cunningham et al., 2017	Cross-sectional	50 stroke (21 RH, 20 LH, 5 BL, 4 subcortical)	21%	64.6 (16.8)	12.84 (10.9) days	Hospital, Ireland	DENA	–	CBS	–	ADL	self-care and household tasks	50
Di Monaco et al., 2011	Cross-sectional	107 RH stroke	50,5%	72.5 USN+, 71 USN-	19 days median	Rehabilitation, Italy	BIT	FIM	–	–	ADL	Independence	100
Edmans and Lincoln, 1990	Case–control	150 stroke (75 RH, 75 LH)	Unknown	68.16 LH, 69.75 RH	1 month	Hospital, England	RPAB	ADL scale	–	–	ADL	Independence and self-care and household tasks	50
Erez et al., 2009	Case-control	72 stroke, 39 healthy controls	Unknown	Unknown	3–12 weeks	Rehabilitation, Israel	BIT, MWCT, VISSTA	FIM	CBS	–	ADL	Independence	100
Eschenbeck et al., 2010	Cross-sectional	68 RH stroke	25 to 32.4%	59.4 (13.3)	134.2 (382.1) days	Hospital, Germany	Star and line cancellation, Line bisection, figure copying, clock drawing, text reading	–	Address copying, dialling, clock reading, face creaming, hair combing, filling out form, tray assembling, counting money	–	ADL	Self-care and household tasks	100
Farne et al., 2004	Case series	33 RH stroke, 10 healthy	69.7%	68 neglect+, 72 neglect−, 68 healthy	<6 weeks from stroke	Unknown, Unknown	Subtest BIT	–	menu reading	–	ADL	Reading and writing	100
Ferro and Kertesz, 1984	Case study	1 RH Stroke	100%	61	2 weeks	Hospital, England	Cancellation and line bisection tests	–	writing and reading	–	ADL	Reading and writing	75
Fong et al., 2007	Cross-sectional	Part 1: 14 stroke; part 2: 54 RH stroke USN+	Part 1: 36%; part 2: 100%	Part 1: 63.9 (13.5); part 2: 69.7 (10.5) (elderly)	Part 1: 129 (185.3); Part 2: 11.9 (7.3) days	Rehabilitation, China	CBIT-HK, clock drawing	FIM	–	–	ADL	Independence	100
Fullerton et al, 1986	Cohort	205 stroke	35%	Unknown	Unknown	Hospital, Ireland	Albert's test, drawing and copying	Unknown	–	–	ADL	Independence	25
Gialanella and Ferlucci, 2010	Case–control	301 stroke	15%	72.7 (7.8)	Unknown	Rehabilitation, Unknown	Albert's test	FIM; TCT	–	-	ADL	Independence	100
Gillen et al., 2005	Cohort	281 RH stroke	Unknown	72.25 (10.75)	14.86 (10.45) days	Rehabilitation, Unknown	letter cancellation	FIM	–	–	ADL	Independence	75
Goedert et al., 2012	Cross-sectional	51 RH stroke	100%	66.9 (15.9)	22.3 (10.9) days	Rehabilitation, Unknown	BIT, CBS	BI	–	–	ADL	Independence	100
Grattan and Woodbury, 2017	Case series	12 RH stroke with VSN	100%	67.75	412.54 days	Rehabilitation, Unknown	star cancellation; line bisection; BIT C	–	BIT B; CBS; NAT, VRLAT (VR)	–	ADL	self-care and household tasks, walking and wheelchair navigation (VR)	100
Halligan et al., 1990	Case–control	54 RH stroke, 26 LH stroke, 50 controls	62.5%	56.2 (10.5)	2 months	Rehabilitation, England	BIT C	–	BIT B	–	ADL	self-care and household tasks	75
Hamilton et al., 2008	Cohort	21 RH stroke with VSN	100%	69.1 (11.3)	21.6 (8.6) days	Unknown, Unknown	Letter cancellation, Picture scanning, menu reading, line bisection, bells test, lateralized response test, lateralized target test	–	menu reading	–	ADL	reading and writing	100
Hartman-Maeir and Katz,1995	Cross-sectional	40 RH stroke	30%	63.9	12.16 days	Rehabilitation, Israel	BIT	–	Performance tasks, ADL checklist	–	ADL	self-care and household tasks	50
Haselbach et al., 2014	Incidence/prevalence	172 stroke (59 RH, 88 LH, 25 both)	34%	52 (11)	<14 days 89 pt, >14 days 83 pt	Rehabilitation, Switzerland	Unknown	FIM	–	–	ADL	Independence	75
Hofgren et al., 2007	Cohort	58 stroke (28 RH, 28 LH, 2 both)	29.1%	52 (7.9)	Unknown	Rehabilitation, Sweden	BNIS	FIM, IAM	–	work	ADL and Participation	ADL: Independence Participation: work	75

Table 1 (*Continued*)

Study, year	Design	Number of patients (hemisphere of lesion)	VSN %	Age, mean (SD), years	Time post-stroke onset, mean (SD)	Setting, country	VSN tests	Outcome measures			Main findings		
								Independence	ADL	Participation	Category	Subcategory	MMAT score %
Houston et al., 2015	Case–control	29 visual field defects, 21 controls	44.8%	Between 32 and 60	Groups median 5–5.5 days	Hospital and other, Finland	Line bisection, bells test	–	Collision	–	ADL	walking and wheelchair navigation (VR)	75
Hreha et al., 2017	Cross-sectional	46 LH stroke with aphasia	12.5%	61	Unknown	Community, Unknown	BIT C, CBS vanuit KF-NAP	BI, LSQ	–	LSQ	ADL and Participation	ADL: Independence Participation: Community mobility and orientation	50
Huitema et al., 2006	Case–control	12 RH stroke, 8 LH stroke, 10 healthy	30%	67.5 RH neglect+, 59.5 RH neglect−, 55.9 LH neglect−, 56.5 healthy	406 RH neglect+, 819 RH neglect−, 447 LH neglect−	Rehabilitation, Unknown	Bells test, line bisection, letter cancelation	FAC, RMI	walking ability	–	ADL	walking and wheelchair navigation	75
Iosa et al., 2016	Cohort	49 RH stroke with VSN	100%	68.79 no pn, 63.59 mild pn, 68.56 severe pn	14.93 no pn, 15.29 Mild pn; 17.06 severe pn	Rehabilitation, Italy	Letter cancellation, barrage test, sentence reading and Wundt-Jastrow test	BI, RMI, CNS	–	–	ADL	Independence	75
Jehkonen et al., 2000	Cohort	57 RH stroke	Unknown	63.23 (10.21)	6.1 (1.97) days	Hospital, Finland	BIT B, BIT C	–	FAI	–	ADL	self-care and household tasks	100
Jehkonen et al., 2007	Cohort	56 RH stroke	37.5%	59 CR, 63.5 FR, 73 PR	6 days	Unknown, Unknown	BIT C	BI	FAI	–	ADL	Independence and self-care and household tasks	50
Katz et al., 1999	Cohort	40 RH stroke	52.5%	57.4 USN+, 58.6 USN−	34.5 USN+, 25.4 USN−	Rehabilitation, Israel	BIT C, LOTCA	FIM, RKE-R	–	–	ADL	Independence	75
Katz et al., 2000	Cohort	40 RH stroke	52.5%	57.4 USN+, 58.6 USN−	34.5 USN+, 25.4 USN−	Rehabilitation, Israel	BIT C, LOTCA	FIM, RKE-R	–	–	ADL	Independence	75
Kinsella and Ford, 1980	Cohort	31 stroke (17 LH, 14 RH)	25.8% (RH)	62	4–6 weeks	Rehabilitation and hospital, Australia	Neuropsycho-logical battery	North wick park Activities of daily Living Index	–	–	ADL	Independence	25
Kinsella et al., 1993	Cohort	27 RH stroke	Unknown	Unknown	2–5 weeks	Rehabilitation and hospital, Australia	Shape cancellation, modified line bisection, circle cancellation	BI	–	–	ADL	Independence	50
Klinke et al., 2015	Phenomenological	12 RH stroke with VSN	100%	61	12 days	Hospital, Iceland	CBS	–	Interviews, observation	Interviews, observation	ADL and Participation	ADL: self-care and household tasks, reading and writing, walking and wheelchair navigation Participation: community mobility and orientation, social roles	100
Klinke et al., 2016	Mixed method	15 RH stroke with VSN	100%	65 median	148.6 days	Hospital, Iceland	CBS, star cancellation, figure copying, line crossing, line bisection, clock drawing, text reading	–	Interviews, observation	Interviews, observation	ADL and Participation	ADL: self-care and household tasks, walking and wheelchair navigation Participation: community mobility and orientation	100
Kong et al., 2016	Case–control	46 stroke (33 LH, 13 RH, 70 healthy)	4.4%	55.2 (12.3) stroke, Healthy unknown	13 patients 8–12 months, 13 patients 25–48 months,		20 patients >5 years	Community, China	HK-OCS; Albert's Test	Chinese version modified BI, IADL-CV	–	–	ADL
Independence	50												
Kongsawasdi et al., 2017	Cohort	146 Stroke	Unknown	Walking 57.5 (15.05); Non-functional mobility 63.2 (11.93)	Unknown	Rehabilitation, Thailand	Unknown	independent walking	–	–	ADL	Independence	50
Kunkel et al., 2015	Cohort	74 stroke	Unknown	76 (11)	Unknown	Hospital, Unknown	Star cancellation	BI, FAC	RMI, activPAL	–	ADL	Walking and wheelchair navigation	75
Lindell et al., 2007	Case–control	34 RH stroke, 31 healthy	77.4%	58.6 (8.02) stroke, 55.2 (13.4) healthy	16.8 (8.9) days	Hospital, Finland	Bit C, shape and letter cancellation, object finding, picture scanning, 2 part picture	–	article reading	–	ADL	reading and writing	75
Louie et al., 2009	Cohort	495 stroke	Unknown	73.34 (11.85)	Unknown	Unknown, China	Line cancellation	Chinese version modified BI, IADL-CV	–	–	ADL	Independence	75

Table 1 (*Continued*)

Study, year	Design	Number of patients (hemisphere of lesion)	VSN %	Age, mean (SD), years	Time post-stroke onset, mean (SD)	Setting, country	VSN tests	Outcome measures			Main findings		
								Independence	ADL	Participation	Category	Subcategory	MMAT score %
Luukkainen-Markkula et al., 2011	Cross-sectional	17 RH stroke with VSN	100%	57 (8)	20 (32) days	Rehabilitation, Unknown	BIT C	FIM	CBS	–	ADL	self-care and household tasks	75
Maeshima et al., 2002	Cross-sectional	32 RH haemorrhage	81.3%	58.7 (9.7)	Within 30 days	Hospital, Unknown	Line cancellation, line bisection, figure copying	BI	–	–	ADL	Independence	50
Marsh and Kersel, 1993	Cohort	27 stroke (17 RH, 8 LH, 2 diffuse)	48%	75.40 (4.96)	17.15 (1.51) days	hospital, New Zealand	line crossing, Star cancellation, paragraph reading, line bisection	modified BI	–	–	ADL	Independence	75
McIntosh et al., 2000	Case–control	31 RH stroke, 13 LH stroke, 44 controls	N=17	65.1 RH N+, 64.4 RH N−, LH, 66.2 controls	3.1 RH N+, 2.7 RH N−, LH months	Unknown, Unknown	Albert's test, line and letter cancellation, Wundt-Jastrow test, drawing a daisy, copying shapes	–	comb and razor,	–	ADL	self-care and household tasks	0
Morone et al, 2015	Cohort	435 stroke	17%	71	14	Rehabilitation and hospital, Unknown	Unknown	BI	–	–	ADL	Independence	75
Nijboer et al., 2013	Cohort	184 stroke	28.8%	57.42 (11.09)	56.1 (29.84) N+, 46.7 (20.31) N−	Rehabilitation, The Netherlands	Letter cancelation	FIM, BI	–	–	ADL	Independence	75
Nijboer et al., 2014	Cross-sectional	118 stroke	31.4%	57.1 (12.2)	35.8 (37.3) N+, 59.0 (12.7) N−	Rehabilitation, The Netherlands	Shape cancellation in 2 distance	BI	CBS	–	ADL	self-care and household tasks	100
Nurmi et al., 2018	Cohort	65 RH stroke, 40 healthy controls	28% N+, 35% MLI	66 healthy, 72 N+, 69 MLI, 65 N-	Medians in days 5 N+, 2 MLI, 3 N−	Hospital, Finland	BIT C	BI	–	–	ADL	Independence	75
Pahlman et al., 2012	Cohort	74 stroke	27%	78 (8)	10.4 (9) days	Hospital, Sweden	Draw mirror image, count number of cubes, copy a cube, line bisection	MRS	Frandin and Grimby scale	–	ADL	Walking and wheelchair navigation	50
Paolucci et al., 2001	Cohort	141 stroke	22.7%	60.53 (13.38)	49.42 (32.44) days	Rehabilitation, Italy	Letter cancellation, barrage test, sentence reading, Wundt Jastrow test	BI, RMI	–	–	ADL	Independence	100
Pedersen et al., 1997	Cross-sectional	602 stroke	23%	73.7 (11.1)	First week	Community, Denmark	Circle cancellation	BI		–	ADL	Independence	75
Peskine et al., 2011	Case–control	9 RH stroke, 9 controls	83.3%	50 (15) RH, 50.6 (16.1) controls	16.1 months	Rehabilitation, Unknown	Bells test, CBS	–	VR task with a virtual town	–	ADL	Walking and wheelchair navigation (VR)	75
Prangrat et al,2000	Mixed method	12 stroke	25%	74 (8.19) UN, 71.44 (6.25) UN-	9.67 UN, 9.56 UN− years	Community, USA	BIT	–	interview, observation	–	ADL	self-care and household tasks	75
Punt et al., 2008	Case series	7 stroke with VSN	100%	67.1	5 years	Unknown, Unknown	Star cancellation, Line bisection	–	power wheel–chair navigation test	–	ADL	Walking and wheelchair navigation	50
Qiang et al, 2005	Cross-sectional	19 RH with hemiplegia	68.4%	65.2 (10.9)	61.9 (25.8)	Rehabilitation, Unknown	CBS	FIM	wheel-chair collision test	–	ADL	Walking and wheelchair navigation	75
Rousseaux et al., 2015	Cross-sectional	54 RH stroke	62%	58 (12.9)	56.2 (28.7) days	Rehabilitation, France	Line bisection, Bells test	–	CBS	–	ADL	self-care and household tasks	100
Sánchez-Cabeza et al., 2017	Cross-sectional	75 stroke (17 LH, 58 RH), 18 health controls	54.7%	55.77 (13.40) stroke, 60.61 (11.76) USN+; 53.38 (11.79) USN−, 47.28 (15.25) healthy	3.20 (3.77) USN+; 4.32 USN−years	Rehabilitation, Spain	BIT C	–	BIT B	–	ADL	self-care and household tasks	75
Said et al., 1999	Case–control	24 Stroke, 22 healthy	37.5%	77.4 (7.9)	27 days	Rehabilitation, Unknown	Unknown	FIM	obstacle crossing	–	ADL	walking and wheelchair navigation	75
Shah et al., 2013	Case study	RH stroke chronic spatial neglect	100%	84	>3 years	Unknown, Unknown	Apple test, BIT, gap detection test, figure copying, bells test	BI	CBS	–	ADL	Independence, reading and writing, walking and wheelchair navigation	75
Stein et al, 2009	Cohort	28 RH stroke	50%	77.7 (8) N+, 74.1 (11) N−	Unknown	Unknown, Unknown	BIT	BI, EMS	–	–	ADL	Independence	75
Stone et al., 1991	Cohort	44 stroke (18 RH, 26 LH), 47 controls	3 days 62% LH, 72% RH and 3 month33%LH 75% RH	71.2 (12.8)	3 days	Hospital, Unknown	VNRI	–	checklist of neglect behaviours	–	ADL	self-care and household tasks	0
Stone et al., 1992	Cohort	68 stroke VSN	100%	Unknown	2/3 days	Hospital, Unknown	VNRI	–	food on a plate, menu reading, selecting coins	–	ADL	self-care and household tasks	50
Stone et al,1993	Cohort	171 stroke (69 RH, 102 LH)	57.3%	72.37 (12.11)	2/3 days	Hospital, Unknown	VNRI	BI	–	–	ADL	Independence	75

Table 1 (*Continued*)

Study, year	Design	Number of patients (hemisphere of lesion)	VSN %	Age, mean (SD), years	Time post-stroke onset, mean (SD)	Setting, country	VSN tests	Outcome measures			Main findings		
								Independence	ADL	Participation	Category	Subcategory	MMAT score %
Sunderland et al., 1987	Cohort	197 stroke (84 RH, 113 LH)	8–11%	70.7 (10)	3 weeks	Community, Great Britain	Greek cross, Raven's coloured progressive matrices	BI	–	–	ADL	Independence	100
Suzuki et al,1997	Cohort	31 stroke	Unknown	In 3 groups: 62.0 (5.8) behavior 1(−), 62.2 (7.2), behavior 1(+) 2(−), 62.6 (6.8) behavior 1(+) 2(+)	56.2 (19.5) behavior 1(−), 57.0 (9.2) behavior 1(+), 58.9 (25.1) behavior 1(+)	Rehabilitation, Unknown	Line bisection and line cancellation, copying of flowers	Evaluation indepen-dency of transfers and gait	ADL observation	–	ADL	Independence	50
Ten Brink et al., 2017	Cross-sectional	325 stroke	15.82% left VSN, 9.25% right VSN	62 left USN, 57 right USN, 61 no USN (median)	28 days left USN, 33 days right USN, 23 days no USN	Rehabilitation, The Netherlands	Shape cancellation and line bisection (digital), CBS	BI, USER	–	–	ADL	Independence	100
Ten Brink et al, 2017	Cohort	113 stroke, 47 healthy	32.74%	59.67 stroke, 56.99 healthy (medians)	37 days (median)	Rehabilitation, The Netherlands	Shape cancellation and line bisection (digital), CBS	BI	MAC	–	ADL	walking and wheelchair navigation	100
Tham et al, 2000	Phenomenological	4 RH stroke with severe extra personal UN	100%	67.75	31.75 days	Rehabilitation, Sweden	Letter cancellation	–	Interviews, observation	Interviews, observation	ADL and Participation	ADL: self-care and household tasks, reading and writing, walking and wheelchair navigation Participation: community mobility and orientation	75
Tham and Kielhofner, 2003	Phenomenological	4 RH Stroke with severe extra personal UN	100%	67.75	31.75 days	Rehabilitation, Sweden	Letter cancellation	–	Interviews, observation	Interviews, observation	ADL	self-care and household tasks, walking and wheelchair navigation	75
Timbeck et al., 2013	Case-control	16 RH stroke	37.5%	76.4 (9.6)	Unknown	Rehabilitation, Canada	BIT	FIM	–	–	ADL	Independence	75
Towle and Lincoln, 1991	Cross-sectional	study 1: 42 RH stroke; Study 2: 56 RH Stroke	Unknown	Study 1: 70.2 (9.5) study 2: 68.5 (9.2)	study 1: 36.2 (19.8) weeks; study 2: 8.6 (5.5) months	Hospital, England	star cancellation, article reading	–	paragraph reading test	–	ADL	reading and writing	75
Towle et al,1991	Cohort	64 RH stroke; 49 relatives	54.69%	Stroke 68.2 (9.7) stroke, 67.8 (5.4) relatives	8.3 (5.3) months	Hospital, England	star cancellation, subtest of the BIT	EADL, Questionnaires	Question-naires	–	ADL	reading and writing	50
Turton et al., 2009	Case-control	15 RH stroke with VSN, 9 controls with stroke	100%	76 RH stroke, 75 controls	39.7 (19.8) days RH stroke, 84.67 days controls	Unknown, Unknown	Star cancellation, line bisection, BIT C, CBS, modified milner landmark	–	Walking and wheelchair navigation test: deviation and collision	–	ADL	walking and wheelchair navigation	75
van Nes et al., 2009	Cross-sectional	78 stroke (44 RH, 34 LH)	21.8%	71.2 (11.6)	5.5 (2.4) days	Hospital, The Netherlands	letter and cancellation	FAC	–	–	ADL	Independence	100
Vanbellingen et al., 2017	Cohort	82 RH stroke	62%	67.87 (13.79)	11.3 days	Rehabilitation, Switzerland	CBS	–	LIMOS	–	ADL	self-care and household tasks	75
Vidovic et al., 2017	Cross-sectional	191 stroke	30.36%	Unknown	Unknown	Unknown, Unknown	Modified line crossing, line bisection and bells test	MRS	–	–	ADL	Independence	25
Viken et al., 2012	Cohort	375 stroke (40 lateralized, 37 non-lateralized, 287 no visual inattention)	11% lat., 10.2% non lat.	58.5 lat., 61 non lat., 56 no visual inatten-tion	12 days lat., 6 days non-lat., 7 days no visual inattention	Hospital, Sweden	Star cancellation	MRS	–	–	ADL	Independence	100
Viken et al., 2014	Cohort	105 RH Stroke	Unknown	53 (10.5) independent, 57.3 (7.5) dependent	3 months	Hospital, Sweden	Star and letter cancellation; Visual search letters, numbers and short words, omissions, initial ipsilateral bias, visual processing speed, repetitions of detections	MRS	–	–	ADL	Independence	100

Table 1 (*Continued*)

Study, year	Design	Number of patients (hemisphere of lesion)	VSN %	Age, mean (SD), years	Time post-stroke onset, mean (SD)	Setting, country	VSN tests	Outcome measures			Main findings		
								Independence	ADL	Participation	Category	Subcategory	MMAT score %
Vossel et al., 2013	Cross-sectional	55 RH Stroke	Unknown	59.3 (13.4)	114.9 days	Hospital, Germany	star and line cancellation, line bisection, figure copying, clock drawing, text reading (BIT)	–	address copying, dialling, clock reading, face creaming, hair combing, filling out a form, Tray assembling, Counting money	–	ADL	self-care and household tasks	100
Webster et al., 1995	Case–control	55 RH stroke, 20 controls	78.2%	62.01 (5.33) L-OMIT, 56.45 (9.22) R-BIAS, 62.58 (8.33) non neglect, 57.55 (9.75) controls	152.25 (181.08) days L-OMIT, 139.90 (214.62) R-BIAS, 167.25 (194.44) non neglect	Rehabilitation, Unknown	Rey-Osterreith complex figure drawing, letter cancellation	–	wheelchair obstacle course (direct hit and sideswipe errors)	–	ADL	walking and wheelchair navigation	100
Wee and Hopman, 2005	Cohort	313 stroke	23% Right VSN, 35% Left VSN, 58% total	76 (8)	37 (22) days	Rehabilitation, Canada	Unknown	FIM	–	–	ADL	Independence	50
Wee and Hopman, 2008	Cohort	309 stroke	27.51% right VSN, 36.57% left VSN, 64.08% total	75.5 (8.1)	37 (22.5) days	Rehabilitation, Canada	line bisection, clock drawing, Rivermead Perceptual Assessment Battery, menu and sentences reading, star, line and Bell's cancellation	FIM	–	–	ADL	Independence	100
Willanger et al., 1981	Mixed method	55 RH Apoplectic brain lesions	32.72%	55% < 70	Unknown	Hospital, Denmark	Unknown	–	Questions, reading	–	ADL	Reading and writing	25
Woszczak et al., 2017	Cohort	63 stroke	39.68%	Unknown	Unknown	Unknown, Unknown	Unknown	BI	RMA	–	ADL	Independence	25

ADL: activities of daily living; BCoS: Birmingham Cognitive Screen; BI: Barthel Index; BIT: Behavioral Inattention Test; BIT B: Behavioral Inattention Test Behavioral subtest; BIT C: Behavioral Inattention Test Conventional subtest; BL: bilateral; BNIS: Barrow Neurological Institute Screen; Baking tray task; CBIT-HK: Chinese Behavioral Inattention Test–Hong Kong; CBS: Catherine Bergego Scale; CNS: Canadian Neurological scale; CR: continuous recovery group; DENA: Dublin Extra personal Neglect Assessment; EADL: Extended Activities of Daily Living Scale; EMS: Elderly Mobility Scale; FAC: Functional Ambulation Categories; FAI: Frenchay Activities Index; FIM: Functional Independence Measure; FR: fluctuating recovery group; Instrumental Activity Measure; IADL-CV: Chinese version of the Lawton Instrumental Activities of Daily Living scale; IAM: Instrumental Activity Measure; IVA-CPT: Integrated Visual Auditory Continuous Performance Test; KF-NAP: Kessler Foundation Neglect Assessment Process; LH: left hemisphere; LHS: London Handicap Scale; LIMOS: Lucerne international classification of function: disability and health-based Multidisciplinary Observation Scale; L-OMIT: omitted stimuli in left hemispace group; LOTCA: Loewenstein Occupational Therapy Cognitive Assessment; LSQ: Life Space Questionnaire; MAC: Mobility Assessment Course: MLI: Mild Left Inattention; MMAT: Mixed Methods Appraisal tool; MRS: modified Rankin Scale; MVPT: Motor-Free Visual Perception Test; MWCT: Mesulam and Weintraub random symbol Cancellation Task; N: neglect; NAT: Naturalistic action test; pn: personal neglect; PR: poor recovery group; R-BIAS: began tasks to the fight without omissions group; r-BIT: reduced version of the BIT-test; RH: right hemisphere; RIF-CAS: Rehabilitation Institute of Chicago Functional Assessment Scale; RKE-R: Rabideau Kitchen Evaluation; RMA: Rivermead Motor Assessment; RMI: Rivermead Mobility Index; RPAB: Rivermead Perceptual Assessment Battery; RWN: Moss Real World Navigation; TCT: Trunk Control Test; Unknown: unilateral neglect; USER: Utrechtse Scale for Evaluation of clinical Rehabilitation; USN: Unilateral Spatial Neglect; VISSTA: VIsual Spatial Search Task; VNRI: Visual Neglect Recovery Index; VR: Virtual Reality; VRLAT: Virtual Reality Lateralized Attention Test; VSN: VisuoSpatial Neglect; VWNT: VR Wheel-chair Navigation Test.

Table 2
Overview of studies: participation.

Study, year	Design	Number of patients (hemisphere of lesion)	VSN %	Age, mean (SD), years	Time post-stroke onset, mean (SD)	Setting, country	VSN tests	Outcome measures			Main findings		
								Independence	ADL	Participation	Category	Subcategory	MMAT score %
Akinwuntan et al., 2006	Incidence/prevalence	68 stroke (45.6% LH, 51.5% RH, 2.9% BL)	Unknown	53 ± 13 years	15 ± 18 months	CARA, Belgium	Unknown	–	–	Component tests of the SDSA, Belgian version TRIP	Participation	Driving	100
Appelros et al, 2003	Case series	131 stroke	Unknown	Unknown	Unknown	Community, Sweden	r-BIT, BTT	Katz ADL Index	Observational	Observational	ADL and participation	ADL: self-care and household tasks, walking and wheelchair navigation; participation: community mobility and orientation	100
Desrosiers et al., 2002	Cohort	132 Stroke (124 RH, 5 LH; 3 BI)	Unknown	60.9 (13.5)	31.3 (13.1) days	Rehabilitation, United Kingdom	Bells test	–	–	LIFE-H version 2.1	Participation	Social roles	75
Devos et al, 2014	Incidence/prevalence	99 Stroke (51 RH, 48 LH)	Unknown	54 (13)	274 (100–519) days	CARA, Belgium	ROCF	–	–	Belgian version TRIP	Participation	Driving	75
Devos et al., 2015	Incidence/prevalence	73 Stroke	Unknown	56 (11)	307 (210–530) days	CARA, Belgium	ROCF	–	–	Belgian version TRIP	Participation	Driving	75
Hofgren et al, 2007	Cohort	58 stroke (28 RH, 28 LH, 2 both)	29.1%	52 (7.9)	Unknown	Rehabilitation, Sweden	BNIS	FIM, IAM	–	Work	ADL and participation	ADL: Independence participation: work	75
Hreha et al., 2017	Cross-sectional	46 LH stroke with aphasia	12.5%	61	Unknown	Community, Unknown	BIT C, CBS vanuit KF-NAP	BI, LSQ	–	LSQ	ADL and participation	ADL: independence participation: Community mobility and orientation	50
Jehkonen et al, 2012	Case study	3 RH stroke	Base line 100%, at driving 0%	67, 58, 38	9, 18, 6 months	On road driving, Finland	BIT C, PP, SIGNAL test	–	On-road driving assessment	On-road driving assessment	Participation	Driving	75
Klinke et al., 2015	Phenomenological	12 RH stroke with VSN	100%	61	12 days	Hospital, Iceland	CBS	–	Interviews, observation	Interviews, observation	ADL and participation	ADL: self-care and household tasks, reading and writing, walking and wheelchair navigation participation: community mobility and orientation, social roles	100
Klinke et al., 2016	Mixed method	15 RH with VSN	100%	65 median	148.6 days	Hospital, Iceland	CBS, star cancellation, figure copying, line crossing, line bisection, clock drawing, text reading	–	Interviews; observations	Interviews, observations	ADL and participation	ADL: self-care and household tasks, walking and wheelchair navigation participation: community mobility and orientation	100
Landi et al., 1997	Case study	1 RH stroke	100%	71	Unknown	Hospital, Unknown	Line bisection; picture copying; cancellation task	–	Play piano, write music	Play piano, write music	Participation	Work	75
Oh-Park et al., 2014	Cohort	31 RH stroke with spatial neglect	100%	60 (11.5)	Within 2 months	Rehabilitation, Unknown	BIT; CBS	–	LSA: Community mobility	LSA: Community mobility	Participation	Community mobility and orientation	75
Tham et al., 2000	Phenomenological	4 RH stroke with severe extra personal UN	100%	67.75	31.75	Rehabilitation, Sweden	Letter cancellation	–	Interviews, observation	Interviews, observation	ADL and participation	ADL: self-care and household tasks, reading and writing, walking and wheelchair navigation participation: community mobility and orientation	75
Viscogliosi et al., 2011a	Cohort	197 stroke (93 RH, 91 LH, 12 BL)	Unknown	76.9 (7.0)	90.4 (79.7)	Community, Canada	Bells test; Montreal-Toulouse reading test	–	–	Life-H	Participation	Social roles	75
Viscogliosi et al., 2011b	Cross-sectional	197 stroke (93 RH; 91 LH; 12 BL)	13.22%	76.9 (7.0)	90.4 (79.7)	Community, Canada	Bells test; Montreal-Toulouse reading test	–	–	Life-H	Participation	Social roles	75

ADL: activities of daily living; BI: Barthel Index; BIT: Behavioral Inattention Test; BIT C: Behavioral Inattention Test Conventional subtest; BL: bilateral; BNIS: Barrow Neurological Institute Screen; CARA: department of the Road Safety Institute; CBS: Catherine Bergego Scale; FIM: Functional Independence Measure; IAM: Instrumental Activity Measure; KF-NAP: Kessler Foundation Neglect Assessment Process; LH: left hemisphere; LIFE-H, life-habits assessment; LSA: Life space assessment; LSQ: Life Space Questionnaire; MMAT: Mixed Methods Appraisal tool; PP: Peripheral Perception test; r-BIT: reduced version of the BIT-test; RH: right hemisphere; ROCF: Rey-Osterrieth Complex Figure; SDSA: Stroke Driver Screening Assessment; TRIP: Test Ride for Investigating Practical fitness to drive; VSN: visuospatial neglect; UN: unilateral neglect.

Table 3
Overview of studies: caregiver burden.

Study, year	Design	Number of patients (hemisphere of lesion)	VSN%	Age, mean (SD), years	Time post-stroke onset	Setting, country	VSN tests	Outcome measures				Main finding	MMAT score %
								Independence	ADL	Participation	Caregiver burden		
Buxbaum et al., 2004	Incidence/ prevalence	166 RH stroke	Any neglect 48%; peripersonal 27%	66.2 U.S. acute, U.S. chronic, 70.5 Italian acute, 63.6 Italian chronic	Between 3 month and 3 years	Hospital, U.S. and Italy	Bells test, letter cancellation, picture scanning, menu reading, line bisection	FIM	–	–	FBQ	Caregiver burden	100
Chen et al, 2017	Mixed method	20 caregivers (10 with care for SN)	50%	56.9	Mean 9.3 months caregiver (8.3 with SN; 9.7 without SN)	Community, Unknown	KF-NAP	–	–	–	GDS, Life Space Question, Time Allocation Questionnaire, Caregiver burden scale, PTSD Checklist	Caregiver burden	75

ADL: activities of daily living; FBQ: Family Burden Questionnaire; FIM: Functional Independence Measure; GDS: Geriatric depression scale; KF-NAP: Kessler Foundation Neglect Assessment Process; MMAT: Mixed Methods Appraisal tool; PTSD: post-traumatic stress disorder; RH: right hemisphere; SN: spatial neglect; US: United States; VSN: visuospatial neglect.

Eight studies met the criteria of the MMAT category "Qualitative design": 3 had a phenomenology design and 5 were case studies. In this category, 7 studies scored 75%. Only 1 study [20] obtained a score of 100%. The quality of the studies scoring < 100% was limited in terms of sources of qualitative data ($n = 2$) and how the findings were related to researchers' influence ($n = 5$).

Finally, 4 studies met the criteria of the MMAT category "Mixed method design": 2 had a sequential explanatory design and 2 a triangulation design. The quality ranged from 25% to 100%.

3.4. Results of individual studies

We divided ADL into independency in ADL, self-care and household tasks, reading/writing and walking/wheelchair navigation. Participation was divided into the subcategories driving, community mobility/orientation, social roles and work.

3.5. Impact of VSN on ADL

A total of 104 studies had ADL as an outcome: 6 qualitative designs, 84 quantitative non-RCTs, 11 quantitative descriptive studies, and 3 mixed-methods studies. The methodological quality ranged from 0% ($n = 2$) to 100% ($n = 32$) (Table 1).

A total of 51 studies focused on (in)dependency during (basic) ADL; 25 used the Barthel Index (BI) and 17 the Functional Independence Measure (FIM) as a single measurement or combined with other measurements. Overall, 27 studies showed that VSN patients were more dependent in ADL than non-VSN patients [4,7,21–45]. The severity of VSN was related to the magnitude of functional independency ($n = 14$) [2,23,46–57]. However, 4 studies found no relation between (severity of) VSN and level of independency in ADL [58–61]. Nine studies measured VSN over time; VSN was a poor predictor of independence of functional recovery [7,62–65] or independence of mobility [66]. The severity of VSN at 24 hours after stroke was a significant predictor of independent activities at 6 months [7,67]. Although patients with VSN had lower independence scores than those without VSN, the difference became smaller over time [7,31]. VSN patients showed a significant improvement during the first year for independence in personal ADL [68].

A total of 31 studies provided results on performance in self-care and household tasks. The BIT ($n = 6$) and CBS ($n = 8$) were mostly used, either as the sole outcome measure or combined with other measures. VSN patients had more problems in performing self-care and household tasks than non-VSN patients [20,26,33,69–87]. For example, VSN patients forgot or could not find objects at one side when dressing or in the kitchen [69,74] and had difficulty eating [74] or using devices [81]. VSN severity had a negative impact on the performance of ADL [88–95]. Dissociations were found between mild neglect in visual screening tasks and moderate or severe neglect in behavior, although for most patients, neglect was equally evident in both tests [96]. One study found no relation between VSN and performance of ADL (e.g., face washing, tray wiping); however, the measurements used were found inadequate [97].

Thirteen studies assessed reading and writing. The presence of VSN was negatively related to reading performance [20,23,33,70,86,98–104]. VSN patients were less accurate [98], omitted left words [70,99–101,103] or columns on paper [33], misread words [102], needed several promptings to read or could not absorb the information [70,103] as compared with non-VSN patients. VSN severity was significantly related to functional outcomes for reading [23,76]. Only one study showed that both the presence of VSN and its severity were significantly related to functional outcomes for writing [18].

Fifteen studies included activities in walking and wheelchair navigation. VSN had a negative impact on walking [69,86,105–107] and wheelchair navigation [20,33,69–71,74,106–109]. VSN patients collided while walking [69,86,106,107] or when navigating their wheelchair [20,33,69–71,74,106–109].

One study found no significant associations between successfully stepping over an obstacle and presence of VSN [110]. VSN had a negative impact on exercise such as walking and jogging [111,112]. VSN severity was related to bumping into objects with a wheelchair [113].

Another 8 studies used VR as a simulation for ADL. VSN had a negative impact on VR navigation tasks in walking and wheelchair navigation [83,114–119]. VSN patients were at risk of colliding [114–118,120], could not detect objects [83,116,117,119] or failed to adapt their strategies [120]. Under dual-task conditions, patients with VSN experienced less avoidance strategies and reduced minimum distances to obstacles [115].

3.6. Impact of VSN on participation

In 15 studies, participation was identified as an outcome measure: 4 had a qualitative design, 6 were quantitative non-RCTs, 4 were quantitative descriptive studies, and 1 had a mixed methods design. The methodological quality ranged from 50% to 100% ($n = 4$); [16,20,69,74]) (Table 2).

Four studies discussed the negative impact of VSN during driving. Poor driving performance was visible in lane changing, understanding, and traffic participation [17,18]. Even among patients showing no VSN on conventional pen-and-paper tests, their driving performance was hampered [19].

Six studies provided data on community mobility and orientation. VSN had a negative impact on regaining functional mobility in the community [25,121]. Patients with VSN had difficulties orienting themselves in the environment and identifying where they were located [20,69,70,74].

Four studies examined the impact of VSN on fulfilling social roles: 3 used the LIFE-H (questionnaire used to estimate the level of participation). VSN was correlated with categorical independent variables but was not the best predictor at 6 months post-stroke [122]. When returning to the community after a stroke, positive changes in participation over time were possible, even with cognitive deficits [123,124]; this study showed that patients with and without VSN have the same level of participation and fulfilling social roles. The fourth study indicated that the change in relationship to other people was the main source of concern for most VSN patients [20].

Only 2 studies described the impact of VSN on returning to work. One study reported that 11% of the patients with neglect or aphasia had resumed working at 1 or 3 years after stroke [68]. The other study reported that a patient could sing and play the piano again but was unable to write a new musical [125].

3.7. Impact of VSN on caregiver burden

Only 2 of the 115 studies discussed caregiver burden. [126,127] The study of Buxbaum et al. (2004) had a quantitative descriptive design and a quality score of 100%. The study of Chen et al. (2017) had a mixed-methods design and scored 75% for quality (Table 3).

VSN independently contributed to predicting family burden [126]. Caregivers of VSN patients were more likely to describe economic stressors and undesirable changes in career and vacation planning than caregivers of non-VSN patients [126]. VSN in stroke survivors was associated with greater burden and stress in caregivers and involved allocating more caregiving as compared with caregivers of non-VSN patients [127].

3.8. Differences between study populations with mean age younger/older than 65 years

Here, we provide according to the second aim, a descriptive overview of differences between studies focusing on populations with mean age < 65 versus ≥ 65 years (Tables 1–3, column 5). Of the 104 studies that reported on ADL (Table 1, column 5), 48 studies had a population with mean age < 65 years versus 47 with mean age ≥ 65 years. Mean age was not reported for 9 studies. Only 1 of 8 studies on VR had a mean age ≥ 65 years. Because overall the main findings did not differ, no difference is expected regarding the impact of VSN on independency and performance during ADL between younger and older persons with VSN.

Of the 15 studies reporting on the impact of VSN on participation (Table 2, column 5), 9 studies had a population with mean age < 65 years versus 4 with mean age ≥ 65 years. In 2 studies, the mean age was not specified. The studies with mean age of the population ≥ 65 years provided data on work ($n = 1$), community mobility and orientation ($n = 1$), and fulfilling social roles ($n = 2$, but from the same authors/population). No studies about driving had a population with mean age ≥ 65 years. Studies on fulfilling roles with population mean age ≥ 65 years showed no relation between VSN and fulfilling social roles, in contrast to studies with population mean age < 65 years ($n = 2$).

Of the 2 studies that provided findings on the impact of VSN on caregiver burden (Table 3, column 5), for 1, the population mean age was ≥ 65 years. From these preliminary findings, there is no indication that these outcomes would differ between younger and older populations.

4. Discussion

The results of this review of 115 studies (quality ranging from 0% to 100%) indicate that VSN had a negative impact on patients' independence and in particular the performance of ADL (self-care, household tasks, reading, writing, walking, wheelchair navigation). Additionally, VSN had a negative impact on participation (driving, community mobility, orientation, work). The impact of VSN on fulfilling social roles remains unclear. VSN had a negative effect on caregiver burden. We found no clear age-related differences. Few studies focused on participation (especially among older patients) and caregiver burden.

4.1. Impact of VSN on ADL

Our findings on independence and performance of ADL are consistent with the review of Jehkonen et al., who concluded that VSN had a negative influence on independence of activities [8]. In contrast, Stein et al. reported no important relationship between hemi-inattention status and functional outcome in patients with right hemisphere stroke because of significant methodological limitations of the relatively few studies published in this field in the last decade [5].

Measuring independence in ADL is useful (e.g., FIM of BI) to produce an overall image regarding functioning, functional recovery and progress. However, an independence measure does not allow for analyzing the problems people experience or to indicate the problems in performance. When VSN is examined with a performance scale (e.g., CBS) better insight in the actual performance of activities is gained as well as an overview of real experienced needs in treatment of VSN or in compensation strategies. With more insight in ADL performance, personal goals can be better described, and treatment can be more adequate, coordinated and adjusted accordingly. A performance measure will help give more information to the patient and caregiver about the treatment, the needs, modifications and preparation both during

rehabilitation and when returning home. We suggest that when assessing VSN, a measurement tool that gives insight in the impact of VSN on performance of activities is needed as well.

Many studies reported a discrepancy between the various VSN diagnostic measurements, particularly when using tests on different levels of outcomes (levels of body function, ADL and participation). For example, pen-and-paper test results differed from results of a measurement for ADL [69,86,108], VR [119], and dynamic measurement [106]. In general, many studies reported that patients who showed VSN during an ADL task did not show VSN on a regular pen-and-paper task. To prevent missing VSN and underrecognizing it, VSN should be assessed at more than one level (i.e., levels of isolated [cognitive] function as well in more dynamic situations).

Overall, a considerable number of different instruments were used to diagnose VSN, which makes comparison and interpretation of the studies difficult and does not benefit research and practice. Therefore, future VSN studies will require consensus on outcome measures for both research and general practice. This requirement applies to all levels of measurements to diagnose VSN in terms of function (i.e., pen-and-paper test) and at the level of activities and participation.

4.2. Impact of VSN on participation

To our knowledge, no other review has examined the impact of VSN on participation. Our findings show that VSN had a negative influence on different aspects of participation and also show considerable variety regarding which aspect of participation showed related problems. The impact of VSN in fulfilling social roles was unclear. Further research is needed to gain more insight into the association between VSN and participation.

4.3. Impact of VSN on caregiver burden

Although we expected to find more studies on the impact of VSN on caregiver burden, only 2 met the inclusion criteria, both associated VSN with a greater burden on caregivers of VSN patients than caregivers of non-VSN patients. The effect of VSN on caregiver burden is underexposed, and more research is needed to explore caregivers' problems and to better guide VSN patients and caregivers in preparation for a return home.

4.4. Difference between study populations with mean age younger/older than 65 years

We found no clear age-related differences in the aspects investigated. The results concerning age differences by level of participation and caregiver burden should be interpreted with caution. Our results indicate that more research in this field is needed.

Although VR is a relatively new instrument to detect problems in VSN activities in a safe environment, we found 8 studies using this instrument. However, 3 were from the same authors [114,115,120], 2 of which included the same population [115,120]. Since only one study had a population with mean age $\geq$ 65 years, [83] more studies are needed on the usability and diagnostic criteria in this older age group.

VSN is a common disorder after stroke in older adults (mean age $\geq$ 65 years), but we found few studies of this population according to level of participation. Further research is needed to gain more insight into the association between VSN and participation, especially among older patients.

4.5. Strengths and limitations

A limitation of this study was the restriction in search strategy. First, our search strategy concerned only studies written in English. Second, because of the large amount of included studies, we did not use a snowball method or include grey literature (e.g., theses).

One strength of this systematic review is the inclusion of both quantitative and qualitative study designs. By using the MMAT for methodological quality assessment, we could assess various types of study designs with one measurement tool within their own category. In addition, using the MMAT could also be considered a limitation. The MMAT can be used for every study design but is therefore also a coarse tool to measure quality. The quality score could differ when using another instrument for quality assessment.

Another strength is that we examined the impact of VSN on three different aspects (ADL, participation and caregiver burden); moreover, the outcome ADL was split into independence and performance. Although many studies have examined independence measures, these instruments do not assess actual performance. Measurements of performance are important for actual insight into the problems people with VSN really experience. More insight can ensure better individual treatment (goals) and better guidance for patients and caregivers for returning home. In the present review, both the inclusion of all study designs and examination of the impact of VSN provided a more comprehensive overview of the impact of VSN on patients and caregivers.

5. Conclusion

VSN has a negative impact not only on patients' independence but particularly on the performance of ADL. Despite the far fewer studies of VSN as compared with ADL, VSN also seems to hamper participation and increases caregiver burden, but further research is recommended. Because of the large impact, VSN should be systematically and carefully assessed during rehabilitation. A considerable number of different instruments were used to diagnose VSN. Diagnosing VSN at more than one level (function [i.e., pen-and-paper test], activities and participation) is strongly recommended. Consensus is needed for research and practice on how to assess VSN and its negative impact.

Funding

This research was made possible in cooperation with Zorggroep Florence, The Netherlands. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Disclosure of interest

The authors declare that they have no competing interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.rehab.2019.05.006.

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