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REVIEW ARTICLE

A scoping review of powered wheelchair driving tasks and performance-based outcomes

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ABSTRACT

Introduction: Wheelchairs and scooters promote participation and have positive effects on quality of life. However, powered wheelchairs (PW) use can be challenging and can pose safety concerns. Adequate PW assessment and training is important. There is a wide variety of tasks and PW driving assessment measures used for training and assessing PW driving ability in the literature and little consensus as to which tasks and outcomes are the most relevant. A scoping review of the literature was performed in order to characterize this extensive variety of tasks and performance-based outcomes used for training and assessing PW skills.
Methods: A search of the literature was conducted in January 2017. Four databases were searched: CINAHL, Embase, PsycInfo and Medline. Articles were included if they contained at least one PW driving task.
Results: 827 articles were screened and 48 articles were retained. PW driving tasks from each article were identified and categorized in terms of the environment in which they were performed: Driving in a controlled environment, ecological driving tasks, 2D virtual environment (VE) tasks, 3D VE tasks. The assessment measures formed a separate category. Subjective and objective performance-based outcomes related to PW driving were also identified and grouped into outcomes assessing speed and outcomes assessing accuracy.
Conclusion: This scoping review provides an overview of tasks and performance outcomes used in the literature when training and assessing PW skills. The results of this review could guide future research when choosing appropriate tasks and performance outcomes for PW driving ability.

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➤ IMPLICATIONS FOR REHABILITATION

- There is wide variety of tasks and performance-based outcomes for PW driving.
- Results showed that available assessment measures are not commonly used in research and that tasks used often lacked consistency across studies.
- New methods to measure the interaction of speed and accuracy are needed.
- The contents of this review could be used by researchers as a starting point when designing a PW task and selecting appropriate performance-based outcomes.

Introduction

Activity limitations due to mobility impairments can restrict social participation and impact quality of life. Wheelchair and scooter users represent around 1% of the Canadian population [1]. Mobility aids such as wheelchairs and scooters can have positive effects on the quality of life of people with disabilities [2,3] and have been shown to increase participation in the community [2,4–8].

Powered wheelchairs (PWs) enable people with more severe disabilities to navigate their environment with less upper extremity involvement than with a manual wheelchair. However, PW use can be challenging and can pose safety concerns. Accidents with powered wheelchairs are common [3,9,10]. A survey of PW and scooter users found that one-fifth of respondents reported having had an accident in the previous year that often resulted in injury or damage to the device [3].

Given the safety concerns involved with PW driving, effective PW training and accurate assessment of a user's driving ability is important. Selecting a set of tasks that adequately reflects a user's PW driving ability is not straightforward. In addition, important considerations have to be taken into account when selecting the type of outcome, either objective or subjective, that will appropriately measure driving ability. There are a few PW driving assessment measures available in the literature, such as the Wheelchair Skills Test (WST) [11] and the Powered Wheelchair Driving Indoor Assessment (PIDA) [12], which have been tested for validity and reliability, however, such tests are not often used [13,14]. In addition, the different tests vary in terms of the tasks that are included and the outcome measures used to assess driving ability. A systematic review conducted in 2003 by Kilkens [15] examined 24 manual wheelchair skills tests and found that studies employed different tasks and outcome measures, making it

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difficult to compare results. A second systematic review of wheelchair skill tests for manual wheelchair users with a spinal cord injury reached a similar conclusion [16]. Lack of consensus between the tests for the tasks that were included and the outcome measures used makes it difficult to compare results between studies. As with manual wheelchair skill tests, there currently exists no consistently used standard set of tasks for the training or assessment of PW skills. Tasks and performance-based outcomes in the literature range from those used in assessment measures such as the WST and the PIDA to ones developed by researchers for a specific research purpose. Thus, there is still a lack of consensus on what constitutes important factors of wheelchair driving ability and on how to measure these factors. In particular, it is unclear as to what aspects of basic wheelchair performance (speed, accuracy, etc.) relate to higher level tasks (e.g., entering a crowded elevator).

As a first step in determining what aspects of wheelchair driving ability should be measured and in what context, we wish to identify all PW driving tasks and their related performance-based outcomes in the literature. This will provide an overview of how these tasks and outcomes are designed for different assessment and training purposes. Whereas the International Classification of Functioning, Disability and Health (ICF) distinguishes capacity (what an individual can do in a standardized setting) from performance (what an individual does in their usual environment) [17], no such distinction was made for this review. All PW driving tasks performed for training or assessment purposes in a clinical setting or in the user's usual environment were reviewed (see Table 1 for definitions and examples of the terms used in the review).

Unlike previous reviews [15,16,18] that have focused on identifying available training protocols and skills tests, our review includes all PW driving tasks and performance-based outcomes. In addition to the available training protocols and skills tests, our review includes studies containing PW tasks and outcomes used for a broader range of research purposes and users.

There are three main objectives to this review:

1. To identify all PW driving tasks and assessment measures related to PW driving ability;
2. To characterize these driving tasks in terms of the skills involved in the execution of the task;
3. To characterize the performance-based outcomes used to evaluate driving ability.

Owing to the broad nature of our research question and our emphasis on identifying and characterizing the evidence that exists in the literature as opposed to the quality of that evidence, we are following the framework of a scoping review rather than that of a systematic review. Thus, for this review, only an inventory of PW driving tasks and performance-based outcomes is presented.

Materials and methods

A scoping review of the literature was conducted using the methodological framework outlined by Arksey and O'Malley [19] as a guide.

Research question

The question we sought to answer with this review was "What are the driving tasks and associated performance-based outcomes that have been used for assessment and training of powered wheelchair driving ability?"

Inclusion–Exclusion criteria

To be included in the review, studies had to be peer-reviewed and contain at least one driving task. The PW had to be controlled with a regular joystick input device. Studies were rejected if the tasks were performed using an input device other than a joystick. PW tasks that were also performed using another device (e.g., scooter or manual wheelchair) for comparison purposes were included. Studies with PW driving tasks that were performed in both real and virtual environments were included. Conference abstracts and short reports were excluded for lack of details on the driving tasks used. Studies that described powered wheelchair driving assessment tools were included in the review if they contained at least one driving task. Self-reported PW driving assessments were therefore excluded.

Literature search

The search was conducted in January 2017. Four databases were searched using keywords: CINAHL, Embase, PsycInfo, and Medline. Subjects headings were selected whenever available (see Table 2 for the keywords and subject headings used in the search).

No specific date range was selected for the search. Titles and abstracts were skimmed to identify relevant studies based on the inclusion criteria. When the details regarding the task were not clear from the abstract, the full article was examined.

The first screening included all articles with joystick-controlled PW driving activities, regardless of their purpose. Because this initial screening was as inclusive as possible, some of the articles retained were found to be of little relevance with regards to our research questions. Hence, the following additional exclusion criteria were defined:

Task not aimed at assessing user driving ability

Some studies contained PW tasks that were not aimed at assessing or training users' driving skills. We rejected studies in which the successful execution of the task did not rely on user driving ability. For example, tasks performed by an experimenter or with

Table 1. Definitions and examples of terms used in the review.

	PW driving skill	PW driving task	PW driving task goal	PW driving performance-based outcome
Definition	Abilities that PW users must acquire in order to drive safely and effectively	Driving activity performed using a powered wheelchair that can be used for training or assessment purposes.	Goal of PW driving task that is explicitly communicated to users or implicitly derived from the task conditions	Aspect of PW driving ability (reflecting *capacity* or *performance* from the ICF) that can be evaluated using objective or subjective measures.
Example	Driving in a straight line	Driving in a straight narrow hallway	Instructions given to user: "Drive as quickly as possible while avoiding collisions with the walls"	Speed, time to complete task, number of collisions

Table 2. Keywords and subject headings used in the literature search.

Database	Keywords and Subject headings
MEDLINE	["power* wheelchair*" OR "electric* wheelchair*" OR "motori#ed wheelchair*"] AND ["task" OR "train*" OR "perform*" OR "learn*" OR Learning/ OR "skill" OR "activit*" OR "program" OR "assess*"]
Embase	["power* wheelchair*" OR "electric* wheelchair*" OR "motori#ed wheelchair*" OR Powered wheelchair/] AND ["task" OR "train*" OR Training/ OR "perform*" OR Performance/ OR "learn*" OR Learning/ OR "skill" OR Skill/ OR "activit*" OR "program" OR "assess*"]
CINAHL	["power* wheelchair*" OR "electric* wheelchair*" OR "motori#ed wheelchair*" OR Wheelchairs, Powered/] AND ["task" OR "train*" OR "perform*" OR "learn*" OR Learning/ OR "skill" OR "activit*" OR "program" OR "assess*"]
PsycINFO	["power* wheelchair*" OR "electric* wheelchair*" OR "motori#ed wheelchair*"] AND ["task" OR "train*" OR Training/ OR "perform*" OR "learn*" OR Learning/ OR "skill" OR "activit*" OR "program" OR "assess*"]

*replaces any number of characters
#replaces any one character

a dummy in the wheelchair were excluded. Tasks performed using intelligent wheelchairs or shared control were excluded because they did not reflect typical driving ability.

Tasks used to test aspects of wheelchair navigation other than driving ability (e.g., vibrations experienced by the PW, immersion factors affecting perception in 3D, muscle activity during PW driving) were rejected. In addition, studies exclusively focused on device maneuverability were rejected. For example, tasks designed to determine the minimum space required for different devices were rejected because the execution of the task did not require skillful driving and depended exclusively on aspects of the device. We retained studies evaluating driving ability using new devices (e.g., comparing performance with different joysticks) if the assessment of driving ability was thought to be focused on the user, i.e., how skilled is this user with this device rather than how well does this device perform.

Exploratory driving and observational studies

Studies in which driving ability was observed without users having to perform a specific task were rejected. We excluded articles that described exploratory driving interventions in which users learn to drive by exploring their environment because there was no clearly defined powered wheelchair driving task. Assessment tools that did not require users to perform a task were not included in the review. Additionally, studies that mentioned skills training without any clearly defined task were rejected.

Review process

Two reviewers screened the articles independently to extract relevant studies based on the inclusion and exclusion criteria described above. When disagreement occurred, the articles were discussed until a consensus was reached.

Charting and coding the data

After the final set of references was agreed upon, the articles were examined closely to extract relevant information. For each article, we charted the purpose of the study, the population for whom the task was designed or tested in the study, a description of the task or tasks and the performance-based outcomes to assess user driving ability. Only PW driving tasks and PW driving performance-based outcomes were extracted. Tasks such as activating the controller or using wheelchair controls and outcomes such as workload and fatigue were not included.

Since the main focus of this review is the powered wheelchair driving tasks, we discussed ways to best categorize or code these tasks. This proved to be less straightforward than anticipated. The final set of articles contained a wide variety of tasks, many of which with multiple sub-tasks, that made categorizing them difficult and not very useful. In addition, most studies contained more than one task, often as part of an obstacle course. Determining when one task ends and another one begins was not always clear. Therefore, rather than categorizing individual tasks, we opted to broadly categorize each article in terms of the environment in which it was performed: Driving in a controlled environment, ecological driving tasks, 2D virtual environment (VE) tasks, 3D VE tasks. The assessment measures formed a separate category.

PW driving skills

As defined in the introduction, PW skills are the abilities that PW users must acquire to drive safely and effectively. There are several ways to design a task to test a skill. For example, the skill of driving in a straight line could be tested using three different tasks:

- Driving in a straight narrow hallway in which the user must avoid collisions with the walls
- Driving straight in an open space, in which the user must drive as fast as possible while maintaining a straight course
- Following a straight line on the floor, in which the user must refrain from deviating from the line

All three tasks are essentially testing the same skill but in different ways. After extracting all tasks from the articles, a list of driving skills was generated by grouping similar tasks together. The tasks were then coded in terms of the driving skills required for each task.

Task goal and performance-based outcomes

Defining a clear environmental goal is essential for any motor task. When mentioned in the articles, the goal for each task was extracted and charted. Since PW driving ability is typically assessed in terms of safety (avoiding collisions, accuracy in driving) and efficiency (speed and accuracy in driving), performance-based outcomes were grouped into outcomes assessing speed and outcomes assessing accuracy.

Results

The initial pool of articles consisted of 827 references (Figure 1). 106 articles containing at least one joystick-controlled PW task were retained after a first screening. After defining additional exclusion criteria, 40 references were rejected from the review because the task did not reflect the user's driving ability. Eighteen exploratory or observational studies were rejected because they did not contain a clearly defined task.

Our final set contained 48 references. Twenty-two articles described real environment tasks and 16 articles contained virtual environment tasks. The remaining 10 references described an assessment measure.

Tables 3–6 describe the articles according to the type of task contained (real tasks in controlled or ecological setting and virtual tasks in 2D or 3D). The articles describing an assessment measure were grouped separately and described in Table 7. The study purpose, population, task description, skills assessed, and performance-based outcomes are summarized for each article.

Real environment driving tasks

Of the 22 articles containing a real environment task, 18 involved driving in a controlled environment. Ten of these used an available assessment measure for their driving ability evaluation [20–29]. The remaining 12 articles are summarized in Table 3 (driving in a controlled setting) and Table 4 (ecological driving tasks).

Most tasks performed in a controlled environment were obstacle courses involving several tasks to be performed in succession as quickly as possible while avoiding collisions [30–33]. Performance-based outcomes largely consisted of the time to complete obstacle course or each section of the obstacle course (speed outcome), as well as the number of collisions (accuracy outcome).

Some tasks required participants to follow a track on the floor and were assessed with the time to complete the track and measures of deviation from the track [34,35].

One task involved driving to different targets as quickly as possible [36,37]. In another study, tasks were drawn from the Wheelchair Skills Test, but assessed using other objective measures of joystick use [38].

Three studies contained tasks that were more ecological in nature and required users to drive in different environments (rehabilitation center and home [39], school, home and outdoors [40] and community [41]. Users often had to interact with their environment (approaching and positioning the PW next to objects, taking an elevator). Outcomes were objective (average speed, task completion time, number of boundary violations and number of collisions) or subjective assessments of driving ability (pass/fail, 7-point ordinal scale).

Virtual environment driving tasks

This is not a comprehensive review of all PW simulators and VEs. Since the focus of the review was on tasks and outcomes, only studies in which a PW task was described were included.

Seven out of the sixteen VE tasks were performed in a two-dimensional environment as opposed to a more realistic three-dimensional environment. These 2D VE tasks are summarized in Table 5. They consisted of maze-like tasks in which the goal is to avoid going out of bounds or touching the walls. The majority of the articles containing such tasks compared driving ability using different joysticks and used performance-based outcomes related to joystick control. Despite the 2D environment not being very realistic, it is an easy way to obtain detailed information on someone's ability to control a joystick for basic skills such as right and left turns and driving in a straight line.

Table 6 summarizes the nine articles describing three-dimensional virtual environment tasks. These 3D VE tasks were more complex in terms of the skills required to perform the task. They aimed to be as realistic as possible and often included validation tasks in the real environment. The outcomes used to assess driving ability ranged from basic information such as task completion time and number of collisions to more detailed information related to joystick control and PW trajectory.

Assessment measures

Ten articles describing PW driving assessment measures were retained for our review (Table 7). Most assessment measures contain many tasks and cover the full range of skills. Assessment of driving ability usually consists of a subjective scoring system using a 4-point scale and is usually done for each individual task. Most measures in our sample had been evaluated for validity and reliability.

PW driving skills

Fifteen driving skills were identified from the PW tasks (Table 8). Some tasks required more than one skill. For example, taking an elevator includes being able to approach and position the wheelchair to reach the call button (approaching and positioning), go through the elevator doors (doorways), reversing into the elevator (driving in reverse) or making a 180-turn in place (turning in place) in a restrained area (maneuvering in a restrained area), positioning the wheelchair next to the button (approaching and positioning) and driving out (doorways).

PW driving Performance-Based outcomes

PW driving performance-based outcomes were extracted for each task and categorized according to whether they assessed speed or accuracy. Associations emerged between task design and outcomes used. Table 9 summarizes objective (quantitative continuous and discrete) outcomes for speed and accuracy categorized by task designs encountered in our sample. Outcomes related to speed were usually the same regardless of task type. Time to complete the task was the most frequently used speed outcome. Outcomes related to accuracy differed depending on the task design. When the task required users to follow a track on the floor, measures of deviation from the track were commonly used. When the task was to drive within boundaries, such as in the 2D virtual maze tasks, the number of boundary violations was often used. These studies also included measures of deviation from an ideal trajectory or centre course. Accuracy for obstacle courses that have no boundaries or track to follow was usually assessed by the number of collisions. Some studies also included measures of joystick control to obtain more information about driving ability.

Driving ability was sometimes assessed with a 4-point or 3-point scale. Skill tests and assessment measures frequently employ this method of evaluation. An observer rates performance on each task using predefined criteria. A total score is often calculated by adding up the scores obtained for each task.

Discussion

Our sample of studies included a wide range of tasks and outcomes. Tasks were categorized according to the environment they were performed in (real vs. virtual, 2D vs. 3D, controlled vs. ecological driving). Most tasks performed in a real environment involved driving under controlled conditions (obstacle courses,

Table 3. RE Tasks – Driving in a controlled setting.

Articles	Purpose	Participants	Task description	Skills assessed	Task goal and performance-based outcomes
Cooper et al. 2000 [35]	To extend Fitts' Law to investigate PW driving performance with an isometric joystick and a position-sensing joystick	Experienced PW users	Driving on a track consisting of: straight sections, right and left quarter-circular turns, semi-circular turns, a complete circle, and driving in reverse	Straight driving simple turns, circular driving, driving in reverse	Task goal: Drive over the course following the track accurately and drive as quickly as possible. Speed outcomes: Average speed (m/s) Accuracy: Root mean square tracking error Speed and accuracy outcomes (from Fitts's Law): Movement time (time to travel 134cm), information processing capacity
Dawson et al. 2003 [30]	To investigate whether PW training with stroke patients with unilateral neglect improved driving performance	Stroke patients with unilateral neglect	Negotiate two doorways and 5 pairs of bilateral obstacles placed 96cm apart	Doorways, fixed obstacles	Task goal: not specified in article Speed outcomes: Total time to complete an obstacle course Accuracy outcomes: Number of left collisions
Dicianno et al. 2006 [37]	To compare driving performance when using a standard motion-sensing joystick and an isometric joystick	Experienced PW users	Drive as quickly as possible to different targets at different distances	Driving straight	Task goal: Participants required to maintain both speed and accuracy Speed outcomes: Reaction time (interval between computer's start beep and first detected joystick signal), movement time (difference between the end of RT and target acquisition) Accuracy outcomes: Driving accuracy (hit or miss - if subject remained on target for at least 2000 ms)
Dicianno et al. 2007 [36]	To characterize subjects' force control strategies from previous study	Experienced PW users	Drive as quickly as possible to different targets at different distances	Driving straight	Task goal: Participants required to maintain both speed and accuracy Speed outcomes: Reaction time (interval between computer's start beep and first detected joystick signal), movement time (difference between the end of RT and target acquisition) Accuracy outcomes: Driving accuracy (hit or miss - if subject remained on target for at least 2000 ms)
Huang et al. 2015 [34]	To determine the effectiveness of joystick-controlled video console games in enhancing subjects' ability to control power wheelchairs	Healthy young adults with no PW driving experience	Driving test: following a track containing straight lines and right and left turns	Straight driving, simple turns	Task goal: Complete the course as quickly as possible Speed outcomes: Completion time Accuracy outcomes: Lateral deviation
Jipp et al. 2012 [31]	To examine the extent to which individual differences in fine motor abilities affect indoor safety and efficiency of human-wheelchair systems	Able-bodied participants	Obstacle course with 14 sections requiring participants to reach targets. Includes driving forward and in reverse, turning in place, making turns and avoiding obstacles.	Maneuvering in restrained area, driving in reverse, turning in place, simple turns, avoiding fixed obstacles	Task goal: Drive without colliding with walls or objects and as quickly as possible while prioritising safety. Speed outcomes: Time required to reach next goal Accuracy outcomes: Number of collisions
Punt et al. 2008 [32]	To investigate the performance of patients with neglect when steering a power wheelchair on two tasks	Patients with unilateral neglect	Wheelchair Assessment Course (WAC): Negotiating 13 obstacles placed in specific and marked locations along a corridor. Includes driving between pairs of obstacles forming gates at the beginning and end of the course. Doorway Accuracy Test (DAT): Navigate a central course though three openings of different widths	Avoiding fixed obstacles, doorways, driving straight	WAC: Task goal: not explicitly mentioned but involves negotiating obstacles. No mention of speed. Accuracy outcomes: Number of collisions, side of collisions DAT: Task goal: Maintain a central course through a series of opening. Accuracy outcomes: Deviation from midline
Punt et al. 2011 [33]	To investigate the ability of patients with neglect to improve their performance when navigating a powered wheelchair	Patients with unilateral neglect	Same as Punt et al. 2008		Same as Punt et al. 2008
Sorrento et al. 2011 [38]	To compare joystick control strategies and performance on standardized driving tasks between expert and novice PW users	Expert and novice PW users	Tasks drawn from a subset of Wheelchair Skills Test. Driving backward 5 m in a straight line, turning 90° (forward and backward, right and left), turning 180° within the limits of a 1.5 m square (right and left), moving sideways from one wall to another in a 1.5 m square (right and left), getting through hinged door (in both directions, pushing and pulling) *Same tasks as Archambault et al. 2012 in simulator (see Table 6)	Driving straight, driving in reverse, simple turns, 180-turn in place, approaching and positioning	Task goal: Complete each task while remaining within the boundaries Speed outcomes: Task completion time Accuracy outcomes: Joystick displacement, joystick excursion, mean number of joystick movements, variability of joystick direction

Table 4. RE Tasks – Ecological driving tasks.

Article	Purpose	Participants	Task description	Skills assessed	Task goal and performance-based outcomes
Hoenig et al. 2015 [39]	To test performance using different mobility devices	Community-dwelling, cognitively intact ambulatory veterans who used a mobility device within the 14 days prior to the study	Community mobility task: drive between rehabilitation clinic and hospital entrance. Includes an elevator, hallways, automatic doors, turns and different surfaces (carpet, stone walkway) Home mobility task: drive to and from bedroom and a bathroom. Includes driving through 3 doorways and navigating to a toilet and a bed. Training tasks: Propelling forward and backward, turning right, left and in a full circle, maneuvering through closed and open doors and alongside objects	Maneuvering in restrained areas, approaching and positioning, simple turns, driving straight, surfaces, doorways, driving in reverse, driving in circular motion	Task goal: not explicitly mentioned in article Speed outcomes: Average speed for each task (distance of paths/time taken to complete task) Accuracy outcomes: Number of collisions
Uustal et al. 2004 [41]	To test a new mobility device, the independence IBOT 3000 mobility system by people with a disability	People who use a mobility device	Community Driving Test (designed for study): Negotiate elevator Up incline One-step entrance One-step exit Negotiate sidewalk Cross street with curb cut Negotiate uneven terrain Negotiate soft terrain Climbs up curb Climbs down curb Retrieves book off high shelf	Approaching and positioning, maneuvering in restrained area, inclines, curbs, surfaces	Task goal: Not specified in article. Scoring system based on participant's ability to perform task Outcome: Score based on whether participant can perform the task independently (vs. with assistance) with low levels of exertion (7-point ordinal scale)
Wolf et al. 1991 [40]	To evaluate functional performance using a new power wheelchair for children and young adults	Single participant – 13 year old able-bodied boy	Functional tasks in simulated home and school environment: Positioning at table and desk and reaching for objects, writing on blackboard, turning on water and turning off light switch. Opening and passing through door, U-turns Maneuvering in a narrow path with right and left turns Straight driving Drive up 10-cm curbs indoor and outdoor Drive on hard-level surfaces, gravel, grass	Approaching and positioning, doorway, 360-turn, simple turns, straight driving, curbs, surfaces	Task goal: different criteria for each task Outcomes: For positioning: pass/fail, distance from trunk to table/desk, height of table/desk above or below xyphoid process For reaching: pass/fail for each height, arm reaching distance, time to completion For driving tasks: time to completion, number of collisions, number of boundary violations For curbs: pass/fail

Table 5. 2 D virtual environments.

Article	Purpose	Participants	VE task description	RE validation or comparison task	Skills assessed	VE task goal and performance-based outcomes
Cooper et al. 2002 [43]	To compare driving performance between a conventional joystick and an isometric joystick	Experienced PW users	Move a sprite representing PW in a straight line, move a sprite around a square and around a circle	Following a track containing straight sections, semi-circular turns, quarter-circular turns and a full circle	Driving straight, simple turns, circular driving	Task goal: Follow the track as accurately as possible and drive as quickly as possible Speed outcomes: Time to complete task Accuracy outcomes: Root-mean-square error (RMSE)
Dicianno et al. 2009 [44]	To evaluate PW driving performance of individuals with tremor using an isometric joystick with and without a WFLC filter, and a motion-sensing joystick	People with a pathological tremor	Track containing a right-hand turn and track containing a left-hand turn	N/A	Simple turns, driving straight	Task goal: Drive as quickly as possible while staying as close to the center of the path Speed outcomes: Time to complete trial Accuracy outcomes: Number of boundary violations, RMSE
Dicianno et al. 2012 [45]	To compare driving performance of people with CP to controls using two different joysticks	People with CP, healthy controls	Maze-like VE tasks with varying number of 90 degree turns and straight sections (paths completely visible or appeared in increments)	N/A	Simple turns, driving straight	Task goal: Drive as accurately as possible while maintaining speed between 0.8 and 1.2 m/s. Speed outcomes: Time to complete task, reaction time, average absolute acceleration, average absolute speed Accuracy outcomes: Average deviation from ideal trajectory (m), standard deviation (SD) of distance from ideal trajectory, number of self-intersecting loops, number of changes in heading
Hasdai et al. 1998 [46]	To evaluate a powered wheelchair driving simulator developed to train and assess children with disabilities	Children with PMD or CP	Drive through mazes of varying complexity while avoiding obstacles	Functional Evaluation Rating Scale developed to assess driving performance (*see Table 7)	Driving straight, simple turns, avoiding fixed obstacles	Task goal: Guide cursor from start to end without hitting walls and barriers. Speed outcomes: Time to complete the maze Accuracy outcomes: number of collisions (Scoring system allocating 1000 points and subtracting 1 point per collision and 1 point per second passed)
Mahajan et al. 2011 [47]	To compare wheelchair driving performance in a driving simulator using a conventional joystick and an isometric joystick	Participants at least 1-year post-TBI	Track with 90-degree left turn, track with 90-degree right turn, drive straight and enter a smaller area, maneuver in a restrained area (All tasks performed forward and backward)	Real PW driving performance rated on 7-point Likert scale: driving straight along hallway and turns	Simple turns, driving straight, maneuvering in restrained area, driving in reverse	Task goal: Drive simulated chair along the center of each task segment as quickly and accurately as possible. Speed outcomes: Average trial completion time, number of times PW is stuck in place for more than 3 seconds Accuracy outcomes: RMSE of deviations from centre, movement offset, movement error, and number of significant changes in heading, number of boundary violations Other: Number of head position monitor violations (measures distraction)
Mahajan et al. 2014[48]	To evaluate driving performance with a variable compliance joystick (VCJ) with customizable algorithms and a conventional joystick	People with MS	*same tasks as Mahajan et al. 2011 (forward only)	N/A	Simple turns, driving straight, maneuvering in restrained area	Task goal: drive as fast as possible without hitting the track boundaries. Speed outcomes: Reaction time, task completion time Accuracy outcomes: Root mean square deviation, movement error, number of collisions, number of significant changes in heading
Riman et al. 2011 [48]	To test computer performance of younger vs. older participants	Healthy young and older adults	2-D virtual hospital wing consisting of straight sections and right and left turns	N/A	Simple turns, driving straight	Task goal: Move computer pointer using force feedback joystick through the path with a minimum number of impacts against the walls. Speed outcomes: Total test time, Accuracy outcomes: Distance efficiency (minimum distance divided by actual test distance) Other: resting time (% of inactivity compared to test time)

Table 6. 3 D virtual environments.

Article	Purpose	Participants	VE task description	Skills assessed	RE validation/ assessment tasks	VE task goal and performance-based outcomes
Adelola et al. 2009 [49]	To develop a training and assessment system to facilitate learning and play by means of virtual reality technology	Case studies: 6-year old male with CP, 17-year old female with CP	Drive in a virtual house by tracking and hitting spherical objects along the way. Scenarios consist of different combination of the following tasks: Forward driving on a straight line, right and left turns, collision-avoidance, emergency-stop, fast drive	Straight driving, negotiating fixed obstacles, simple turns	"Functional tasks" in RE for assessment of PW skills learned in the VE: turn left or right, stop before hitting a wall, travel forward along a sidewalk without going out of bounds	Task goal: Tracking and hitting spherical objects while driving in the virtual house Speed outcomes: None Accuracy outcomes: Percentage of tasks completed successfully (tempered by the number of guide balls successfully tracked and the accuracy of hit during the tasks)
Archambault et al. 2012 [42]	To validate the use of the miWe simulator by comparing driving performance of healthy adults with the simulator and in a real environment	Healthy adults	Tasks drawn from a subset of Wheelchair Skills Test. Driving route involved driving backward 5 m in a straight line, opening a door, moving through the doorway and closing it (in both directions, pushing and pulling), turning 180° within the limits of a 1.5 m square (left and right), turning 90° forward (left and right), turning 90° backward (left and right), and moving sideways from one wall to another in a 1.5 m square (left and right) *same tasks as Sorrento et al. 2011 in RE (See Table 3)	Driving straight, driving in reverse, doorways, 180-turn in place, simple turns, approaching and positioning,	Same tasks in RE for validation	Task goal: Not specified in article Speed outcomes: Task completion time Accuracy outcomes: PW trajectory, joystick X and Y amplitudes, joystick excursion, number of joystick movements
Harrison et al. 2002 [50]	To test the application of two virtual environments for training and assessing inexperienced PW users	Novice PW users	First VE: Driving 10m in a straight line Driving 2m in reverse 180 turn around object Slalom around obstacles Driving the wheelchair in and out of an enclosed space *did not include route-finding task	Driving straight, driving in reverse, driving in circular motion, driving in a slalom, driving in a constrained area	Same tasks in RE for validation	Task goal: not specified Speed outcomes: Time to complete tasks Accuracy outcomes: Number of separate maneuvers, distance traveled, total number of collisions
Headleand et al. 2016 [51]	To develop and evaluate the Wheelchair-Rift simulator	N/A	Driving through a virtual multi-story building. A virtual elevator is used to access different floors, on which there are specific training scenarios. Current scenarios include: a lobby, where users complete simple tasks to familiarize themselves with the simulator; a simple maze, requiring the user to make several turns and maneuver through doorways, reaching to press a series of buttons to open doors; floating balls: the user has to navigate the environment and touch the blue balls with their hands while avoiding collisions with the red balls, requires the user to make precise, turns and maneuvers. On the fourth floor the user must move through a room activating buttons in a sequence while avoiding collisions with various human-size obstacles that move randomly around the room	Simple turns, doorways, approaching and positioning, negotiating fixed and moving obstacles	N/A	First study evaluating the simulator. No driving performance-based outcomes were measured. Driving performance will be assessed in a future study
Kamaraj et al. 2016 (2 articles) [52,53]	To assess interrater reliability (article 1) and intra-rater reliability and stability (article 2) of the PMRT	PW athletes	Simulation of an indoor office space with a kitchen, lounge area, and a set of hallways lined by offices. Tasks from the PMRT (see Table 7) are incorporated in the VE.	Tasks from PMRT (see Table 7)	N/A	Scored using PMRT criteria (see Table 7). Future goal to provide quantitative metrics Performance subscale of the NASA-TLX used as a user's self-reported performance measure

(*continued*)

Table 6. Continued.

Article	Purpose	Participants	VE task description	Skills assessed	RE validation/ assessment tasks	VE task goal and performance-based outcomes
	when administered through the Virtual Reality-based SIMulator-version 2 (VRSIM-2)					
Linden et al. 2013 [54]	To determine the efficacy of a custom-made wheelchair simulation in training children to use a powered wheelchair	Typically developing children	Four levels of increasing difficulty. Level 1: simple turns and obstacles Level 2: slalom courses in addition to simple turns Level 3 included more acute turns, gaps of varying widths, and low gradient ramps Level 4 included the most acute turns, a variety of gaps, and ramps of varying incline	Simple turns, negotiating fixed obstacles, inclines, doorway	Used the Functional Evaluation rating scale (from Hasdai 1998, see Table 7) for assessment before and after training with in the VE	Task goal: Navigate around a fixed route, remaining on the path and avoiding colliding with objects Speed outcomes: Completion time Accuracy outcomes: Number of collisions/ errors Speed and accuracy: Total score calculated as [0.1/ (collisions*time to completion)]*10,000,000
Niniss et al. 2006 [55]	To investigate the driving characteristics of skilled and unskilled PW users to define quantitative evaluation criteria	Healthy novice PW users and experienced PW users	Fictive outdoor environment containing roads, paths of different widths and shapes, traffic lights and obstacles (stationary and moving). Includes a broken line, a wide straight line, a left half turn followed by a right half turn, a left turn, a narrow straight line with variable width, a complex path, a path with a 5-degree slope, a path with a 10-degree slope, and a straight line with a transversal slope	Driving straight, simple turns, negotiating fixed and moving obstacles, inclines, transversal slopes	N/A	Task goal: In scenario mode, follow a pre-defined path to reach destination point Speed outcomes: Time to complete task Accuracy outcomes: Number of collisions, difference between PW's trajectory and reference trajectory (area between the two trajectories) Defined two new evaluation criteria based on joystick position along the x-axis: one based on its amplitude and one on its Power Spectral Density
Tao et al. 2016 [56]	To evaluate a low-cost magnetic-based hand motion controller as an interface for reaching tasks within the miWE simulator	Experienced PW users	Desk: Parking between two chairs at a desk and pulling the drawer to place an object in it Elevator: Pressing elevator call button, entering the elevator and pressing on floor button Door: Approaching a door, opening it outward and going through doorway	Approaching and positioning, doorways	Same tasks in RE	Task goal: Instructions given on the task requirements, does not mention speed or accuracy. Participants performed tasks "as they saw fit" Speed outcomes: Task completion time Accuracy outcomes: Number of joystick movements, joystick excursion, driving errors (collisions), qualitative analysis of driving behaviour *did not include outcomes related to reaching

Table 7. Powered wheelchair driving assessment measures.

Assessment measure	Authors	Population	Task description	Driving skills assessed	Psychometric properties	Scoring
Powered Mobility Program (PMP) [57]	Furumasu et al.	Children	Basic mobility skills (driving tasks only): pushes joystick to engage PW in motion for 5s, stops on command; stops spontaneously to avoid stationary objects. Directional control: navigates PW in forward direction for 10 feet and 35 feet; turns PW to the right and to the left starting from stationary position; moves PW backward on command (min 2 feet); drives wheelchair forward making right and left curving turns following a person over a distance of 50 feet; veers spontaneously to avoid stationary object. Speed control: driving forward very slowly for 15 feet; changes speed to respond to commands; stops at door; stops at line Integration of basic skills – structured environment: maneuvers PW through doorway; moves parallel along a wall; maneuvers PW through pathway with two turns. Negotiating a ramp. Negotiating a sidewalk. Integration of basic skills – unstructured environment: driving down hallway while avoiding fixed and moving obstacles; maneuvering in open, busy area with fixed and moving obstacles; maneuvering along sidewalk and down a ramp; maneuvers in and out of small office space; avoiding different road surfaces	Driving straight, simple turns, circular driving, avoiding fixed obstacles, avoiding moving obstacles, going through doorways, driving on different surfaces, ramps, transversal slopes, maneuvering in restrained area, approaching and positioning, driving in reverse	Validity: skills included in assessment were identified by clinicians as those needed to maneuver a PW safely Reliability: inter-rater agreement and intra-rater agreement demonstrated	6-point ordinal scale based on amount of hands-on assistance and/or verbal cueing that occurred during the final session
Power Mobility Road Test (PMRT) [58]	Massengale et al.	PW users	Structured tasks: Approaching people and furniture Starting and stopping PW at will Passing through doorways 90-degree R and L turns Driving straight forwards Driving straight backwards Turning 180-degrees Starting and stopping upon request Turning right and left upon command Driving straight forwards in narrow hallway Maneuver between objects Unstructured tasks: Avoid unexpected obstacles (ball and person) Moving person Wet floor sign	Approaching and positioning, doorways, simple turns, driving straight, driving in reverse, 180-turns, negotiating fixed obstacles, avoiding moving obstacles	Reliability: Inter-rater and intra-rater reliability demonstrated when implemented in VR simulator (Kamaraj 2016) Validity: Tasks taken from existing PW performance assessment measures (PIDA, Functional Evaluation Scale, and the Power Mobility Functional Evaluation Tasks)	4-point ordinal scale: Completely independent, optimal performance (4) Unable to complete task (1)
Functional Evaluation Rating Scale (FERS) [46]	Hasdai et al.	Children and young adults	Starting and stopping wheelchair at will and upon request Driving straight in open area Driving straight in narrow corridor Passing through doorways Doing a 360 90-degree corner Backward in a straight line Approaching people or furniture Drive to the target location Turning right and left at will and upon command Planning a trip from one location to another	Driving straight, doorways, 360-turn, driving in reverse, approaching and positioning simple turns	Content validity established, good inter-rater reliability	4-point ordinal scale Very good (1) Unable to perform (4)
Obstacle Course Assessment of Wheelchair User	Routhier et al.	MW and PW users	Moving down a narrow corridor, between cones, and through a doorway Getting over a 2.5 cm doorstep Getting over a 7.5cm doorstep Getting onto a 5.0cm sidewalk curb	Driving straight, doorways, curbs and thresholds, surfaces, inclines	Demonstrated good reliability and construct validity	Task execution time Degree of ease measured on a 4-point ordinal scale: total success (3), complete failure (0)

(*continued*)

Table 7. Continued.

Assessment measure	Authors	Population	Task description	Driving skills assessed	Psychometric properties	Scoring
Performance (OCAWUP) [59,60]			Getting onto a 15.0 cm sidewalk curb Moving on a carpet Moving on gravel 6–19mm Going up and down a 6 m incline of 1:16 Going up and down a 6 m incline of 1:12 Going up and down a 6m incline of 1:8			
Power Mobility Community Assessment (PCDA) [61,62]	Letts et al.	PW users	Driving on sidewalk Driving in the parking lot Driving on road Driving in crowds Maintaining a straight course Intersection with lights Intersection without lights Crosswalks Accessing crosswalk button Crossing streets without lights Using wheelchair accessible transit Manoeuvring on different surfaces Accessing public spaces	Transversal slopes, approaching and positioning, driving straight, avoiding moving obstacles, surfaces, inclines	Face and content validity established	4-point ordinal scale for each task Optimal performance (3) Unable to perform task even with assistance (0)
Power Mobility Indoor Driving Assessment (PIDA) [12]	Dawson et al.	PW users	Bedroom: Accessing bed, approaching dresser, bedroom closet Bathroom: doorway, opening door, approaching sink, toilet, exiting bathroom and close door Doors: Automatic doors, narrow door Elevator Parking Ramps Intersections 180 turn Straight backward Congested area Driving between chairs Unexpected obstacles	Approaching and positioning, driving in constrained area, doorways, inclines, 180-turn, driving straight, driving in reverse, negotiating fixed and moving obstacles	Content validity established. Moderately good intra-rater reliability, very good inter-rater reliability	4-point ordinal scale for each task Completely independent, optimal performance (4) Unable to complete task (1)
Indoor Mobility Skills Course (IMSC) [63]	Walker et al.	People who use mobility devices	Opening and closing a door toward and away Level driving forward and reverse directions Figure 8s Driving up and down an incline Turning in place both in the right and left directions Moving on a cross slope with both a right and left slope Going up and down 1.5-in. curb and 2-in. curb Driving or walking over uneven terrain	Approaching and positioning, driving in reverse, figure 8s, inclines, turning in place, transversal slopes, curbs, surfaces	N/A	4-point ordinal scale for completion and safety: completed task safely (4), maximum safety risk (1) Time to complete task
Community Mobility Skills Course (CMSC) [63]	Walker et al.	People who use mobility devices	Opening and closing a door toward and away Level driving forward and reverse directions Figure 8s Turning in place both in the right and left directions Moving on a cross slope with both a right and left slope Going up and down 1.5-in. and 2-in. curbs Driving over uneven terrain Driving up and down an incline	Approaching and positioning, driving in reverse, figure 8s, turning in place, transversal slopes, curbs, surfaces, inclines	N/A	4-point ordinal scale for completion and safety: completed task safely (4), maximum safety risk (1) Time to complete task
Transfer Assessment Instrument (TAI) [64]	McClure et al.	Wheelchair users	Transfer from wheelchair to mat, or mat to wheelchair	Approaching and positioning	Acceptable inter-rater reliability, wide range of intra-rater reliability	Qualitative scoring system
Power Mobility Clinical Driving	Kamaraj et al.	PW users	Indoor: Drives forward 15 ft (in a straight line) in 36″ hallway	Driving straight, doorways, avoiding moving obstacles, simple turns, turning in place, approaching and positioning,	Good content validity established by the iterative approach with over 50 experts	Score for each task: 3-point ordinal scale Completes task without help (3)

(*continued*)

Table 7. Continued.

Assessment measure	Authors	Population	Task description	Driving skills assessed	Psychometric properties	Scoring
Assessment (PMCDA) [65]			Drives backward 10 ft in a straight line in 36″ hallway Passes through 36″ doorway Avoids therapy balls approaching from left and right Turns 90° while moving forward Turns 90° and enters a doorway Turns 90° while moving backward Turns 180° in place to the left Can safely maneuver in-between 2 chairs 32 in apart Approaches an accessible sink Approaches a transfer surface (bed or chair) Negotiates over 1 in door/mock threshold Stops on command (emergency stop) Outdoor: Drives forward 30ft in 30 s Drives over an unpaved surface Ascends 5° incline Descends 5° incline Ascends 10° incline Descends 10° incline Crosses a street Rolls 10 across 5° side-slope Ascends an ADA curb cut Descends an ADA curb cut	thresholds, surfaces, inclines, transversal slopes		Requires physical assistance or cannot complete task (1)
Wheelchair Skills Test (WST) [11, 66]	Kirby et al.	PW and MW users	Driving forward short distance Driving backward short distance Turns in place Turns while moving forwards (slalom around pylons) Turns while moving backwards (slalom in reverse) Drives forward longer distance Avoids moving obstacles Ascends and descends slight incline Ascends and descends steep incline Rolls across side-slope Rolls on soft surface Gets over threshold Gets over gap Ascends and descends low curb Maneuvers sideways in a tight space Reaches high object Picks object from floor Level transfer Gets through hinged door Gets from ground into wheelchair	Driving straight, Driving in reverse, turning in place, slalom, avoiding fixed and moving obstacles, doorways, inclines, transversal slopes, surfaces, thresholds, curbs, approaching and positioning, maneuvering in restrained area	Content validity, construct validity, concurrent validity Inter-rater and intra-rater reliability, test-retest reliability	Score from 0-2 for each task Performed task independently and safely (2) Did not complete task (0)

Table 8. Powered wheelchair driving skills and their relationship with clinical assessment measures.

	PMP	PMRT	FERS	OCAWUP	PCDA	PIDA	IMSC	CMSC	TAI	PMCDA	WST
Basic Manoeuvring											
1. Driving straight	✓	✓	✓	✓	✓	✓	–	–	–	✓	✓
2. Simple 90-degree turns	✓	✓	✓	–	–	–	–	–	–	✓	✓
3. Circular driving	✓	–	–	–	–	–	–	–	–	–	–
4. Slaloms and figure 8s	–	–	–	–	–	–	✓	✓	–	–	–
Obstacles											
4. Avoiding fixed obstacles	✓	✓	–	–	–	✓	–	–	–	–	✓
6. Avoiding moving obstacles	✓	✓	–	–	✓	✓	–	–	–	✓	✓
7. Going through doorways or gates	✓	✓	✓	✓	–	✓	–	–	–	✓	✓
Environmental or architectural barriers											
8. Driving on different surfaces	✓	–	–	✓	✓	–	✓	✓	–	✓	✓
9. Slopes, inclines, ramps	✓	–	–	✓	✓	✓	✓	✓	–	✓	✓
10. Curbs and thresholds	–	–	–	✓	–	–	✓	✓	–	✓	✓
11. Transversal or curved slopes	✓	–	–	–	✓	–	✓	✓	–	✓	✓
Skilled Manoeuvring											
12. Manoeuvring in restrained area	✓	–	–	–	–	✓	–	–	–	–	✓
13. Driving in reverse	✓	✓	✓	–	–	✓	✓	✓	–	–	✓
14. Approaching and positioning wheelchair next to objects	✓	✓	✓	–	✓	✓	✓	✓	✓	✓	✓
15. Turning in place	–	✓	✓	–	–	✓	✓	✓	–	✓	✓

Table 9. Summary of speed and accuracy outcomes (objective) for different tasks.

		Accuracy		
	Speed (efficiency)	*Following a track*	*Driving within boundaries (mazes)*	*Obstacle courses*
Continuous	Time to complete task Speed Reaction time Acceleration	Lateral deviation, RMSE	Deviation from ideal trajectory (RMSE, average deviation, SD of deviation)	Measures of joystick control (joystick excursion, joystick displacement, variability of joystick direction)
Discrete	Number of times the wheelchair is stuck in place for more than 3 seconds	–	Number of changes in heading, number of boundary violations	Number of collisions, number of joystick movements

following a track). Two-dimensional virtual environment PW tasks were usually very simple mazes designed to compare driving ability using different joysticks. The performance-based outcomes provided detailed information on joystick control. Tasks in three-dimensional virtual environments were more realistic and allowed users to perform complex tasks safely.

Similar to what has previously been reported, we found no standard or consistency between the various tasks or outcomes used to assess PW driving ability. Our sample of studies included a wide range of research questions and PW driving tasks. Despite the availability of reliable assessment measures, the results of the review suggest that these are not commonly used in research. Most studies in our sample contained tasks that were created to suit a specific research purpose. The task descriptions often lacked sufficient details to allow for replication and comparison of PW driving ability. Assessment tools, on the other hand, are usually much more detailed in terms of the task description and requirements. They tend to include a wide spectrum of skills and often require a lot of time, space and resources to administer. Consequently, their use in a research context as opposed to a clinical setting may not be ideal. Another drawback is the way PW driving ability is assessed. The majority of assessment measures use an observational evaluation method, in which driving ability is rated by an observer on a 4-point scale. While this is suitable in a clinical setting, assessment of PW driving ability for research purposes often requires more precise objective outcomes, depending on the research question. A possible solution is to use a subset of tasks from an available assessment measure and to combine it with objective performance-based outcomes. This has been exemplified in two studies [38,42] where tasks were drawn from the Wheelchair Skills Test but assessed using objective outcomes (task completion time, measures of joystick control such as joystick displacement). Combining an available assessment measure with objective outcomes allows researchers to precisely assess driving ability while making use of a clearly defined set of tasks and makes comparisons between studies using the same tasks possible. However, such precise objective outcomes can be difficult to obtain in a clinical setting because they require specific instruments (e.g., instruments to measure joystick control or PW trajectory) that are not readily available. The use of virtual reality makes it possible to obtain detailed information on joystick control and PW trajectory.

In addition to the tasks not always being described in detail, the task goal was often not clearly defined in the articles. Having a clear environmental goal is important for any motor task. This is especially significant for PW driving because of the tradeoff between speed and accuracy that exists when aiming to drive as quickly as possible while avoiding collisions or going off track. Some users may focus on accuracy and drive slowly to avoid deviating from the course or making collisions. Others may try to optimize speed and be less careful in their driving. Defining a task goal that emphasizes both speed and accuracy equally may lead drivers to employ different strategies and could make comparisons difficult. An outcome that takes the interaction of speed and accuracy into account might better reflect driving ability than speed and number of collisions alone. Most studies in our sample placed equal weight on speed and accuracy. Only two studies accounted for the speed-accuracy tradeoff and assessed driving ability using an outcome that combined both speed and accuracy.

While most studies in our sample required users to drive as fast as possible while avoiding collisions, articles describing an outcome measure to be used for assessment and training purposes placed more emphasis on accuracy. In a clinical setting,

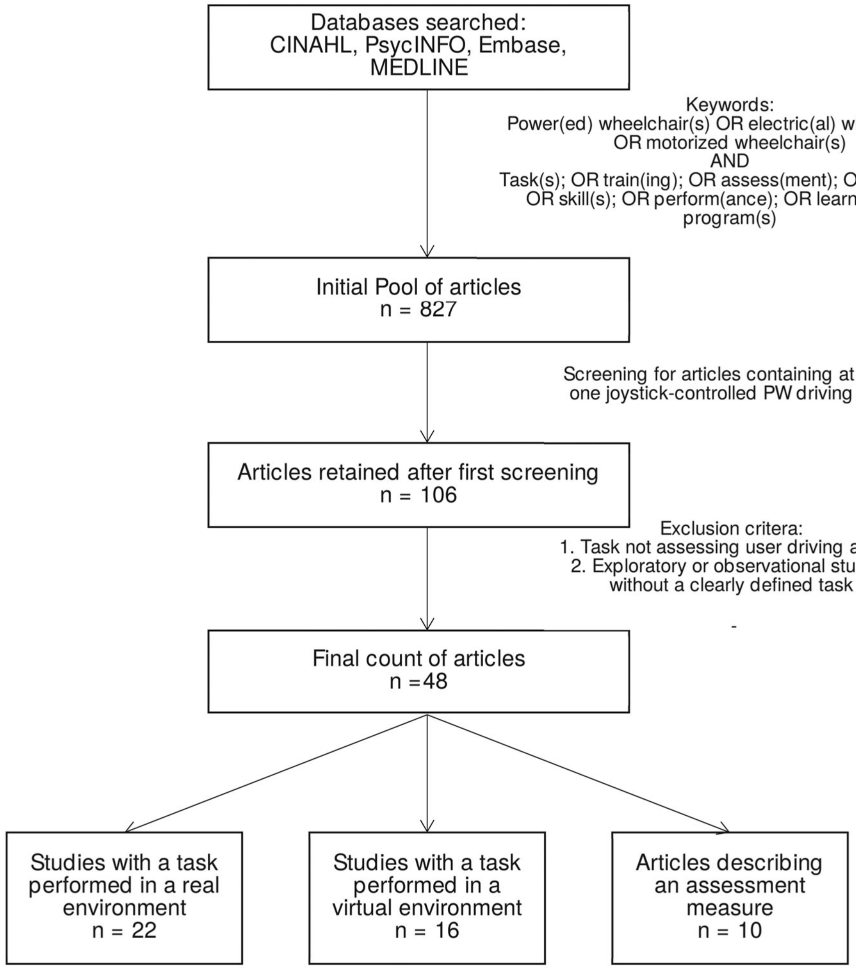

Figure 1. Flow of articles throughout the study.

users are usually taught how to execute a PW driving task in detail and are evaluated on their ability to safely complete it, rather than the speed at which they perform it [11]. In real life, speed is not as important as accuracy and therefore PW assessment and training protocols focus more on accuracy. Other studies reviewed focused less on learning and the PW tasks usually involved driving as fast as possible while maintaining accuracy, suggesting that accuracy may be more important in the beginning stages of learning, but that both speed and accuracy are important for overall driving ability.

Out of all the assessment measures retained for this review, the Wheelchair Skills Training Program was the most comprehensive in terms of the skills categories it encompasses. It is easily available and its measurement properties have been well-established. The tasks, environmental goal and the scoring system are all well-defined. Because quality assessment is outside the scope of a scoping review, no conclusion can be drawn on the validity of using one task or performance-based outcome versus another and is thus a limitation of this study. Future work could involve systematically reviewing tasks and outcomes for validity using a set of predefined criteria. By opting not to distinguish between capacity and performance as outlined in the ICF model, our discussion and categorization of the assessment measures do not reflect this important dimension. Another limitation of the study is that we restricted ourselves to peer-reviewed articles, and thus neglected the extensive grey literature that exists on PW driving.

Conclusion

The purpose of this review was to identify PW tasks and performance-based outcomes used in the literature. Previous reviews have focused exclusively on wheelchair assessment measures [15,16]. By including all PW tasks used for training or assessment of driving ability, our aim was to have an overview of the tasks that have been used for research purposes. Our sample included a wide variety of tasks and performance-based outcomes for PW driving. Results showed that available assessment measures are not commonly used in research and that tasks used often lacked consistency across studies. A good option may be to combine a subset of tasks from an assessment tool with objective outcomes appropriate for research. Performance on individual tasks could then be compared between studies. Virtual reality allows for detailed information on PW driving ability.

Few performance-based outcomes incorporated both speed and accuracy as a single construct. New methods to measure the interaction of speed and accuracy are needed. The contents of this review could be used by researchers as a starting point when designing a PW task and selecting appropriate performance-based outcomes.

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