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Techniki kierowania pojazdem kierowcy z niepełnosprawnością ruchową

Driving techniques for drivers with mobility disabilities

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Abstract. "Driving technique is the way of moving on the road consciously chosen by the driver. The key to proper driving technique is the knowledge, skills and characteristics of the driver" (Cargo, 2023). The above statement applies only to the manner of using the vehicle by a competent driver or candidate for a driver. Using proper driving techniques while driving can prevent mistakes from being made in emergency situations. Generally accepted driving standards and rules do not regulate how to drive a vehicle adapted to the needs of a disabled driver. These skills are therefore not developed either during the course preparing disabled candidates for the driving profession, or at a later stage after obtaining a driving license. The aim of the article is to present methods of driving using the most popular adaptive devices used by people with mobility disabilities. The study used the case study method, i.e. a case study involving the analysis and discussion of real situations. The aim of the article is to answer two questions: what should you pay attention to in the case of driving techniques adapted to the needs of a driver with a disability? Do additional mobility devices used in the vehicle for this group affect the way the vehicle is driven? The lack of information on driving techniques adapted to the needs of disabled drivers is a gap that needs to be filled. The work describes processes related to driving techniques using the most commonly used adaptation kits.
Keywords: person with physical disabilities, paraplegia, disabled driver, vehicle adaptation, car driving technique

Abstrakt. „Technika jazdy to świadomie wybrany przez kierowcę sposób poruszania się po drodze. Kluczem do właściwej techniki jazdy jest wiedza, umiejętności i cechy kierowcy" (Cargo, 2023). Powyższe sentencja dotyczy wyłącznie sposobu korzystania z pojazdu przez sprawnego kierowcę lub kandydata

na kierowcę. Wykorzystanie odpowiednich technik prowadzenia pojazdu podczas jazdy może zapobiec popełnieniu błędów w nagłych sytuacjach. Ogólnie przyjęte standardy i zasady jazdy nie regulują sposobu prowadzenia pojazdu przystosowanego do potrzeb niepełnosprawnego kierowcy. Umiejętności te nie są zatem rozwijane ani na kursie przygotowującym kandydatów z niepełnosprawnością do zawodu kierowcy, ani na późniejszym etapie, po uzyskaniu prawa jazdy. Celem artykułu jest przedstawienie sposobów prowadzenia pojazdu z wykorzystaniem najpopularniejszych urządzeń adaptacyjnych, z których korzystają osoby z niepełnosprawnością ruchową. W badaniu wykorzystano metodę studium przypadku, czyli studium przypadku polegające na analizie i dyskusji sytuacji rzeczywistych. Celem artykułu jest odpowiedź na dwa pytania: na co należy zwrócić uwagę w przypadku technik jazdy dostosowanych do potrzeb kierowcy z niepełnosprawnością? Czy zastosowane w pojeździe dodatkowe urządzenia wspomagające mobilność tej grupy wpływają na sposób prowadzenia pojazdu? Brak informacji na temat technik jazdy dostosowanych do potrzeb kierowców niepełnosprawnych to luka, którą należy wypełnić. W pracy opisano procesy związane z techniką prowadzenia pojazdu z wykorzystaniem najczęściej stosowanych zestawów adaptacyjnych.
Słowa kluczowe: osoba z niepełnosprawnością ruchową, paraplegia, kierowca z niepełnosprawnością, adaptacja pojazdu, technika kierowania samochodem

Introduction

Mobility is one of the basic human needs that influences an individual's social and professional activity. The inability to move freely causes difficulties in meeting basic human needs. Dependence on the help of third parties significantly limits an individual's activity in society (Malawko et al., 2018).

The law supporting the mobility of people with disabilities has been sanctioned by many legal acts, national and international documents. The most important documents include the UN Convention on the Rights of Persons with Disabilities, ratified by Poland in 2012, the Charter of the Rights of Persons with Disabilities (M.P. on 13.08.1997 r. No. 50, item 475), the European Disability Strategy (European Disability Strategy, 2023), and the Constitution of the Republic of Poland. In art. 32 section 1 of the Constitution of the Republic of Poland we read that: „Everyone is equal before the law. Everyone has the right to equal treatment by public authorities", and in section 2 that: „No one may be discriminated against in political, social or economic life for any reason" (Journal of Laws of 1997, No. 78, item 483).

Problems related to the possibility of free movement using public transport (availability of rolling stock, infrastructure and services) cause people with disabilities to choose individual transport. The ability for a person with a mobility disability to drive a vehicle is of paramount importance to it. In many cases, it is the only form of travel.

Cars for disabled drivers consist of adapting their functionality to manual operation, in such a way that a person with paraplegia should rely solely on their hands. This task can become difficult, given that the subject must control all the functions of the same limb (de Freitas et al., 2019).

Driving technique is intended to provide the driver with knowledge and skills in controlling the vehicle and correctly performing manoeuvers. Driving a car involves a process of many configurations. In the case of a driver with a disability, it becomes

important to understand the interconnectedness between them and the adapted cars they use (Barbosa, et al., 2021). Legal provisions apply only to able-bodied drivers (Cargo, 2023). The lack of appropriate records and publications relating to how to drive an adapted car creates a gap that needs to be filled.

Assistive technologies are one of the options to assist drivers with disabilities. Their use is due to their disability. Drivers with disabilities are therefore the target users of assistive technology devices (Duplaga, 2011).

The following study concerns driving a car adapted to the needs of a person with a mobility disability. According to data collected by PWPW, in 2021, 437 driving license documents were issued informing about the need to use an adapted vehicle (Table 1).

Table 1. Number of driving license documents that have restriction codes.

Year of document issue - driving license	**Number of documents issued - driving licenses with code 107 (Poland only)**	**Number of documents issued - driving licenses with sub-codes 10,15,20,25,31,32,33,35,40,42 (EU)**
2018	446	29
2019	431	33
2020	349	17
2021	404	33

Source: A. Wnuk, B. Stasiak-Cieślak, People with disabilities as a traffic accident participant in a road safety database in Poland transport problems (2023) Volume 18 Issue 1, 219-228.

The presented analysis refers to the number of driving license documents containing restriction codes. The summary shows that people with disabilities constitute a fairly large group among drivers. The need to include adaptive car driving techniques in various forms of education seems justified.

Driving a vehicle requires the driver to have adequate physical and mental fitness. Improving qualifications related to proper and safe driving on the roads is an objective that a driver should set for himself. Preliminary activities, correct driving position, correct steering wheel operation, precise use of the acceleration pedal and brake are the key to achieving high technical driving efficiency. Described elements determine the driving technique. Conditions that, apart from driving technique, significantly affect driving safety include:

- ability to properly operate devices used to control the vehicle,
- ability to correctly assess permanent and changing situations in road traffic,
- the ability to reliably assess one's own driving capabilities,
- ability to properly perform road manoeuvers.

The driver should not only notice the relevant stimuli, but also correctly evaluate them from the point of view of their importance. Decisions made by the driver while driving are of routine character. However, one should not forget that driving a car does not only include standard situations. In emergency road situations, one should not forget about the technical condition of the vehicle and the physical and mental capabilities of the driver. Physical disability does not in any way limit the ability to think logically or make decisions. In the case of people with mobility disabilities, it is important to select appropriate adaptive devices. Selecting the appropriate adaptation kit is an individual matter and depends on the driver's subjective feelings (Ucińska et al., 2013).

Driving technique is undoubtedly a skill that affects road safety. The steering wheel is the most important device in every vehicle. Using the steering wheel, the driver receives an important signal while driving about what is happening to the front axle of the vehicle. The way one uses the steering wheel is important for controlling the vehicle, which is related to the safety of both car occupants and other road users. Therefore, the way in which one should keep hands on the steering wheel, as well as the skills related to the acceleration and braking process, seem to be important. According to the adopted rules, the vehicle driver should always hold the steering wheel with both hands. Comparing the steering wheel to a clock face, the left hand should be at 9 o'clock and the right hand at 3 o'clock. The described position causes the hands to be as far apart as possible, which makes it easier to perform the turning manoeuver. Additionally, this setting means that switches and levers located under the steering wheel are within the reach of straight fingers, which allows them to be operated without having to take one's hands off the steering wheel. The technique of accelerating affects not only the smoothness of the vehicle's movement. The ability to react quickly and accelerate appropriately may prove to be an important element in responding to road hazards. The vehicle's braking technique affects safety when an unexpected obstacle suddenly appears on the vehicle's path. One should note that pressing the brake pedal does not stop the vehicle immediately. In order to stop the vehicle, the so-called braking distance I needed, which depends not only on the individual skills of the driver but also on many other elements, e.g. weather, type and condition of the road surface, vehicle tires.

Review of literature and legal acts

The work entitled "Disabled driver in road traffic: comprehensive support for mobility" discusses broadly understood mobility of people with disabilities. The authors described the needs and rights of drivers with disabilities. The material describes cases of people with congenital disabilities, as well as drivers with acquired disabilities. Attention was drawn to how important an element of everyday

life for people with motor disabilities is an adapted vehicle. Legal aspects relating to the mobility of people with physical disabilities were presented. The processes of diagnosing a driver with dysfunctions are described. The materials describe the course of pilot research aimed at verifying the state of knowledge in the area of using automotive services. The final conclusions describe the direction in which the sector dedicated to the surveyed people should develop. It was noted how the mechanisms for systemic operation of supporting diagnosing and financing mobility should be constructed, taking into account the progress of technology (Ucińska et al., 2016).

The research work titled „Re-education of a driver after a stroke - a case study" by Stasiak-Cieślak B., Malawko P., Szczepański T., Kosmowski P. discusses the issue of trying to return to the previous state of health after a stroke. For the purposes of the discussed topic, a number of literature items similar to the subject of the work were analysed. Careful analysis of the legislative provisions was undertaken. The following part of the work describes the rehabilitation process enabling the return to driving. The entire diagnostic process is described, including the examination of the driver's professional certification and the opinion of a transport psychologist in connection with the described case. The final conclusions describe the indications that should be taken into account during tests aimed at verifying drivers' return to driving after a stroke (Stasiak–Cieślak et al., 2021).

In the work by Paczkowski A., Więckowski D., entitled „The need for an objective assessment of the ability to drive vehicles by disabled people", they discuss the issue of lack of standardization of training processes for disabled driver candidates. Taking up the alleged topic, the authors described the stages that a candidate driver must complete in order to be admitted for the state driving test. The paper describes the problems encountered by candidates with mobility and hearing disabilities. The authors drew attention to the significant need to integrate people with disabilities with society, with regard to the mobility of people with disabilities. The work suggests the direction in which the standards for educating candidate drivers should be considered and indicates what provisions will allow for the unification of the above-mentioned process. The final conclusions included indications of the principles and requirements that examination centres should meet in terms of accessibility for people with various types of deficits (Paczkowski et al., 2017).

In the research material by Ucińska M., Dobrzyńska M., Odachowska E. entitled „Driving a vehicle by people with disabilities - mobility and fitness assessment", specific cases of drivers with disabilities and the principle of interpretation of their verification of predisposition to drive a vehicle are described. Describing the verification process of a driver with disabilities, the authors emphasized that it is a largely individual process that requires flexibility from the team when diagnosing and assessing a specific case. The material contains a description of a number of diagnostic activities enabling the assessment of psychomotor skills of many types of dysfunctions occurring in drivers with disabilities. The equipment used for

research, on the basis of which psychophysical properties are also determined, is also described. The acquired knowledge can be used when selecting adaptive devices in an adapted vehicle (Ucińka et al., 2013).

The article entitled „Assessment of the impact of training improving driving techniques on skills to drive a passenger car" by Kamińska J., Bubnowska V., illustrates an attempt to take of measuring the effectiveness of training on changing the habits of professional drivers. The material describes driving techniques used during driver training. For the purposes of research analysed were 212 cases of professional drivers. Data was collected on the number of errors made by the driver while driving on the test track. After obtaining the results, it turned out that they indicated quantitative and qualitative improvement during the manoeuvers performed, including controlling a skidding vehicle, avoiding obstacles during the implementation of test runs. In the final considerations, the authors showed their willingness to continue further work on the collected materials, focusing on the results of drivers, whose results turned out to be unsatisfactory in relation to the intended training effects (Kamińska et al. 2012).

In the training material of the Police Training Centre in Legionowo entitled „Car driving technique" by Hołoweńko S., Jagielski Z., Szczech R., instructions on how to drive a car were developed. The study is addressed to people who want to improve their qualifications for proper and safe road driving. The document contained a description of the elements, activities and dependencies related to proper driving of the vehicle. The material is based on the authors' experience acquired during training in improving driving techniques. The practical exercises included in the document and a detailed explanation of their implementation are intended to demonstrate the correct behaviour of the driver (Hołweńko et al., 2013).

According to WHO, a person with a disability is one who cannot independently, partially or completely ensure the possibility of a normal private and social life as a result of congenital or acquired physical or mental impairment (WHO, 2023).A disability cannot be the only argument that disqualifies a person from being a driver. For some types of disabilities, a car is the only means of transport. Pursuant to the Act of January 5, 2011 on vehicle drivers (Journal of Laws of 2011, No. 30, item 151, as later amended), a person with a disability may drive a car if he or she obtains a medical certificate stating that there are no health contraindications to driving a vehicle (Article 3(3), Article 24 point 2). The driving license held may contain certain restrictions (Article 13(4) and (5)). The restrictions mentioned most often refer to the conditions in which the driver cannot drive the vehicle, as well as the use of adaptations in the vehicle (Journal of Laws of 2011r. No. 30, item 151 as later amended). A person with a disability is subject to the same legal conditions as an able-bodied person. Regulation of the Minister of Infrastructure of June 28, 2019, on the examination of persons applying for driving licenses, training, examination

and obtaining authorizations by examiners, and template documents used in these matters. (Journal of Laws of 2019, item 1206).

Article 66 section 1 point 1, section 2 and section 4 of the Act of 20 June 1997 Road Traffic Law (Journal of Laws of 2023, item 1047, as later amended) specifies the general technical conditions that should be met by a vehicle authorized for traffic. According to the assumption, the vehicle is to be built, equipped, and then maintained in such a way that its operation does not endanger the safety of other road users. Additional vehicle equipment, such as adaptation, should operate efficiently and effectively and not affect the vehicle's structure. Alterations to the vehicle are prohibited except in certain clearly defined exceptions (Journal of Laws of 2023, item 1047 as later amended). In the case of a vehicle adapted to the needs of a disabled driver, the legislator does not impose an obligation to subject the car to additional technical inspection. The exception are changes contained in the registration certificate (item „Official Annotations") (Stasiak–Cieślak et al., 2016). Taking into account the safety of the vehicle user and other road users, certified adaptive devices should be used. Correct installation and regular service inspections are particularly important for driving comfort and correct operation of the installed devices.

Research method.

Preliminary activities, correct positioning in the driver's seat, correct operation of the steering wheel, the ability to accelerate and brake in order to safely stop the vehicle are the key to achieving high technical efficiency. The described activities can be called driving techniques. Questions should be asked here - what should one pay attention to in the case of driving techniques adapted to the needs of a driver with a disability? Do additional devices supporting the mobility of this group used in the vehicle affect the way the vehicle is driven?

In the case of people with disabilities, there are no clear guidelines regarding how to drive an adapted vehicle. The way of driving the vehicle and using adaptive devices is based on the driver's individual habits. During the observation, attention was paid to certain relationships affecting the ability to drive a vehicle. Depending on the set of adaptive devices used, the way of using the steering wheel and the way of performing the manoeuver differs. The resulting differences in driving technique were associated with the need to include additional activities responsible for the operation of additionally applied solutions for drivers with mobility disabilities. The need to perform additional activities forces the driver to develop new patterns.

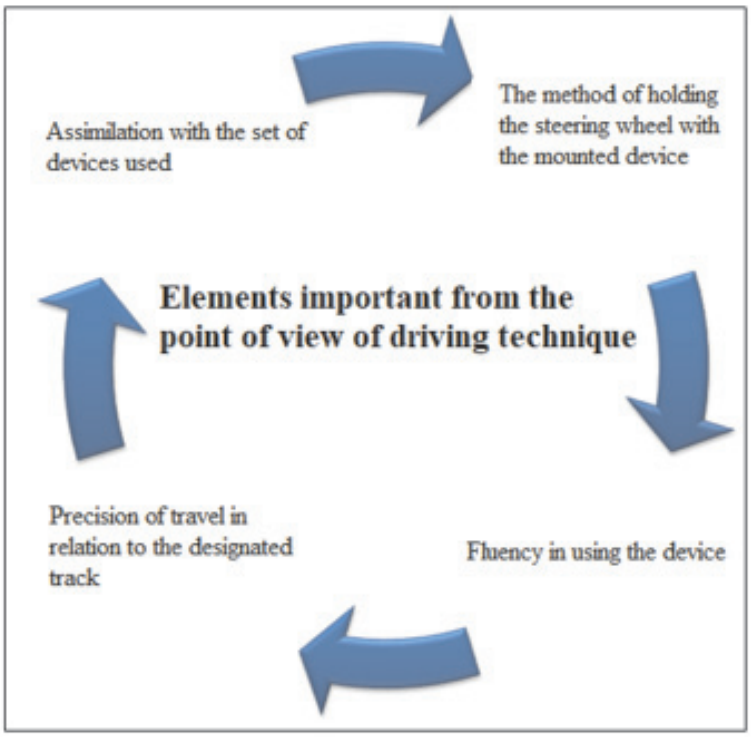


Fig. 1. Observation elements

Source: Own study Assimilation with the adaptation used / The way of holding the steering wheel with the device mounted on it / Elements important from the point of view of driving technique / Precision of the run in relation to the designated track / Smoothness in using the device

The prepared study does not ensure the preparation of a disabled person to pass the state driving test, nor the preparation of a driver who already has the right to drive an adapted vehicle who, due to an accidental situation, became a disabled person. The publication aims to indicate the correct behaviour of drivers using adaptive devices and to popularize the topic of mobility for people with special needs.

Two cars with automatic transmission were selected. The cars belong to the fleet of adapted vehicles of the Automotive Services Centre for disabled people operating at the Motor Transport Institute in Warsaw (Table 2). Device sets installed in vehicles are the most frequently chosen adaptations among drivers with mobility disabilities.

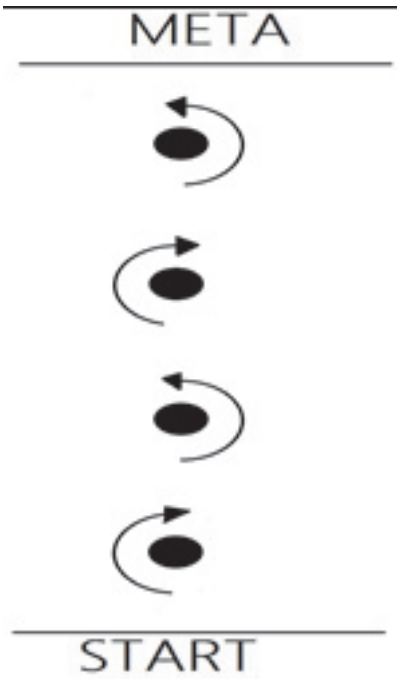
Table 2. Description of vehicles adapted to the needs of drivers with mobility disabilities.

Cars adapted to the needs of drivers with mobility disability	
Skoda Yeti	Skoda Fabia
	
Vehicle equipment	
• DSG automatic gearbox, all-wheel drive. • Veigel handle - a device that allows to control the steering wheel with a remote-control function using one upper limb, usually intended for people with a good hand grip. • Veigel Classic device - intuitive acceleration/brake lever. To accelerate, one needs to turn the handle clockwise. A light pressure forward activates the brake, which can also be locked effortlessly (Veigel 2023) [access 11.09.2023].	• DSG automatic gearbox, front-wheel drive. • 916R Ghost device - a rotating electronic accelerator in the form of a hidden rim under the steering wheel. The controller installed in the device allows for intuitive selection of force and movement when performing turning manoeuvres. Transferring the hand to the brake lever is performed without collision with other devices (GUIDOSIMPLEX Polska, 2023) [access 12.09.2023]. • D907FV Mechanical Brake Lever - Steering column-mounted, space-maximizing mechanical brake system for intuitive braking. The device is also equipped with a horn and a brake lock. Necessary for hill starts and the proper use of the automatic transmission in a car (GUIDOSIMPLEX Polska, 2023) [access 12.09.2023].

Source: Own study

The "Slalom Test" [Table 3.] exercise allows to test how to operate the steering wheel and one's ability to accelerate and brake. Using the steering wheel quickly and efficiently allows the driver to maintain control of the vehicle even in dangerous situations. In the case of the exercise used as part of the observation, it was not about the speed of performing manoeuvers, but about observing the skills of the driver.

Table 3. Description of the "Slalom test" exercise

Slalom test	
	• The exercise is performed in a closed area. To perform the task, cones are placed in a straight line from the start. The length of the slalom and the number of obstacles depend on individual arrangements, taking into account, among other things, the size of the vehicle. • The exercise is not about speed, but the precision of the manoeuver. The ability to properly apply acceleration and brakes as well as precision allows to illustrate the level of assimilation of the driver with the adaptation kits in the vehicle. • The test directly relates to the situation a driver encounters when driving a vehicle on a winding road. Therefore, the driver undertaking the exercise must perform it in a safe and secure manner [Hołoweńko et al., 2013).

Source: Own study based on S. Hołoweńko, Z. Jagielski, R. Szczech, Car driving technique (2013)

The "slalom test" exercise performed during the observation took place in a closed area belonging to the Motor Transport Institute in Warsaw. During the observation, there were optimal weather conditions that did not hinder the performance of manoeuvers (moderate sunlight and dry surface). Observations were carried out at approximately 11:00 at an ambient temperature of approximately 26°C. The driver performed 10 test runs on each car. The test section was each 30 m in a straight line, with the cones marking the track placed every 7 m. The space used between the cones was adapted to the dimensions of the test vehicles.

Fig. 2. "Slalom test" track
Source: Own study

Observation results

As part of the observations conducted, a driver with a motor disability was selected who, using adapted vehicles, was to perform an exercise used to improve driving technique. The description of the exercise and how to use the devices was presented to the examined person in the form of short oral information. Currently, there are no training materials on how to drive a vehicle using adaptive devices. The driver of the vehicle relied on short verbal instructions from the person conducting the test, his habits and skills acquired during the driving course. The pilot study involved 29 years old women with paraplegia, who had been using an active wheelchair since birth. Her both upper limbs are fully functional and had no other deficits. The lower limbs are disabled, with no ability to operate the accelerator or brake pedal. The driver has had authorization to drive a category B vehicle for 12 years. The following restriction codes are used in the driving license document related to driver impairments (Table 4).

Table 4. Analysis of the driving license document

Specification of the driving license document of the disabled driver participating in the study	
	**10.02** – automatic gearbox, **20.06** – manually controlled brake, **25.04** – manually controlled acceleration, **43.01** - driver's seat raised for a good viewing height, at a normal distance from the steering wheel and pedals (person of short stature)

Source: Own study

The course of observation begins with preliminary activities and taking an appropriate driving position. An important issue related to the safety and psychological comfort of the driver is the efficiency of the vehicle he or she is driving. A person with reduced mobility may have difficulty performing some basic preliminary activities before driving [Table 5.].

Table 5. Initial activities in relation to a driver with mobility disabilities

Difficulties with initial steps for the driver with mobility disabilities	
	• checking and optionally adding oil in the engine, • checking the condition of the coolant, brake fluid, windshield washer fluid, • checking the wheel attachment and tire air pressure.

Source: Own study

Assuming the appropriate driving position by the driver affects the safety of driving. The height of the driver's seat significantly affects the ability to see an obstacle and avoid it. In the case of disabled people who use a wheelchair from birth, lower

trunk parameters may be observed. Therefore, these people often need additional support, which should be used to improve visibility. The driver perceives what is happening to the vehicle being driven directly through the seat backrest and steering wheel. It is important that the pads used by short people are as stable as possible and do not move while driving.

When adopting the right driving position, there are two important distances to consider in order to maintain an optimal driving position. We are talking about the distance between the driver's seat and the control pedals and steering wheel. In the case of people with mobility disabilities who use adaptive devices, only the distance of the backrest from the steering wheel should be taken into account. This distance is intended to allow to freely operate the steering wheel without having to take one's back off the seat backrest while performing manoeuvres. The position occupied by the driver behind the wheel depending on the type of adaptation is described below (Table 6).

Table 6. Distance of the driver's seat from the steering wheel in relation to adaptive devices

Description of determining the distance of the seat backrest from the steering wheel	
	 Handle on the steering wheel Lever hand throttle/brake
• We set the distance from the driver's seat in such a way that it is possible to grasp the furthest point on the steering wheel along with the rim with a slightly bent hand, in a position where the back rests directly on the seat. • If we apply the principle of comparing the steering wheel to a clock face, the farthest point for the left hand is at 1 o'clock, while for the right hand it is at 11 o'clock.	• We set the distance of the driver's seat in such a way that the vehicle driver can grasp the farthest point the knob mounted on the steering wheel with his slightly bent left hand and the gas/brake lever with his slightly bent right hand. • Using the principle of comparing the steering wheel to a clock face, place the handle at 9 o'clock. Please remember that this height is adjusted to the individual circumstances of the driver.

Source: Own study

In the case of adaptive devices, in addition to the standard steering wheel operation, the driver must use an additional device, e.g. a knob mounted on the steering wheel or a rim. The type of adaptation selected has a significant impact on the way the driver can operate the steering wheel.

The selection of adaptive devices for a driver with a disability is an individual matter. Currently, there are no legal provisions regulating how to adapt a vehicle to the needs of a disabled driver. Adapting companies and driver training centres offer support in choosing equipment. The selection of a set of devices is based on the analysis of preserved and unpreserved functions of the body. Properly adjusted adaptation allows to drive the vehicle freely and safely. The type and level of advancement of the solutions used should therefore be supported by an appropriately conducted preliminary interview (Stasiak–Cieślak, 2018). Depending on the type of adaptation, we observe differences in the way the steering wheel is held (Table 7).

Table 7. Ways of keeping one's hands on the steering wheel in vehicles equipped with specialized adaptations to the needs of people with mobility disabilities.

The way of holding the steering wheel using adaptive devices	
	• Adaptation of the accelerator/brake lever type requires one to operate the steering wheel with one hand. The left hand rests on the steering wheel and the right hand operates the accelerator/brake lever. It is recommended to also use a knob mounted on the steering wheel for this type of adaptation. The above-mentioned device allows to use the steering wheel more efficiently when performing manoeuvres. Additionally, in the case of many knobs that can be found on the market, we can find knobs that enable operation of other functions (e.g. turn signals) that are important for driving a vehicle.
	• Rim-based adaptations allow the vehicle to be driven in a manner similar or close to standard. Both hands rest on the steering wheel so that they grasp, both the steering wheel and the rim at the same time. Only the braking process forces the driver to move his right hand to the brake lever while driving the vehicle. When driving the vehicle using the rim, similarly to the standard way of holding the steering wheel, the left hand was at 9 o'clock and the right hand was at 3 o'clock.

Source: Own study

Undoubtedly, the most important skill of a driver is correct and quick operation of the steering wheel. This skill is important in sudden and unexpected situations that occur while driving. The driver's knowledge and skills in dealing with various situations affect the safety of the driver and other road users. Quickly turning the steering wheel to the right or left is called a manoeuvring turn (Integrated Educational Platform of the Ministry of Education and Science, 2023). The way of using the steering wheel can be observed based on the previously described slalom test used to improve vehicle driving techniques. Commonly accepted schemes do not fully reflect the situation in which the driver uses additional devices supporting his or her mobility. The method of operating the steering wheel varies depending on the adaptation sets used (Table 8, 9), as well as the driver's individual preferences resulting from his or her disability and the habits and patterns that were instilled in him during the driving course.

Table 8. Case study of the technique of using the knob mounted on the steering wheel

Starting position	
	• The left hand holds a handle in the form of a knob, which is mounted at a height of 5 cm from the steering wheel. Assuming that the steering wheel is compared to a clock face, the knob is located at 8 o'clock (driver's individual preferences). • The right hand is placed on the lever of the manual throttle-brake device throughout the manoeuvers. • Regardless of the type of manoeuver performed, the handle in the form of a knob, rotating on an axis, allows to perform the manoeuver without having to take one's hand off the steering wheel.
Manoeuvring position	
	• The left hand pushes the steering wheel to the right, forcing the vehicle to turn right, until it reaches the highest point on the steering wheel (12 o'clock). Passing this point, pushing force turns into a force pulling the knob down. The work of the left hand after crossing the lowest point on the steering wheel (6 o'clock) changes the pulling force into pushing. The action performed forces the vehicle to turn left.

Source: Own study

The method of using the steering wheel depends strictly on the type of adaptive device set used. If a knob-shaped handle is used, the steering wheel can be operated using only one hand. The mounted handle in the form of a knob is intended to support the driver while driving, as well as to provide a more secure grip on the steering wheel when the technique differs from the standard scheme. The Ghost type rim installed in the second vehicle used for testing allows for a hand position similar to the standard one used by a non-disabled driver. Each of the journeys made during the observation was recorded in the form of a video recording. The recordings show that 95% of the time, the driver can operate the steering wheel with both hands at the same time, assuming that the driver only removes his hand when braking the vehicle. In relation to the conducted observation, the braking process referred to stopping the vehicle during the start and after the end of the test. The driver sporadically used the brake lever during the manoeuver itself.

Table 9. Case study of the technique of using the Ghost type hoop

Starting position	
	• Both hands grip the steering wheel with the Ghost type rim. • The hands position is similar to the standard pattern. • As in the case of a steering wheel without a rim-type adaptive device, we hold our hands in a position where the left hand is at 9 o'clock and the right hand is at 3 o'clock. • The right hand leaves the steering wheel only during the process of braking the vehicle.
Manoeuvring position	
	• The left hand pushes the steering wheel with the Ghost device in the right direction and the right hand follows the steering wheel. The performed manoeuver forces the vehicle to turn right. • When the left hand is at 12 o'clock, the highest point of the steering wheel, the right hand takes over the task of pulling the steering wheel and the Ghost type device. The performed manoeuver forces the vehicle to turn right.

Source: Own study

The ability to react quickly and accelerate appropriately may prove to be an important element in responding to road hazards. For example, the correct use of vehicle braking techniques can increase safety when an unexpected obstacle suddenly appears on the vehicle's path. The process of acceleration and deceleration depending on the type of adaptation is described below (Table 10).

Table 10. Case study of the technique of accelerating and braking using adaptive devices

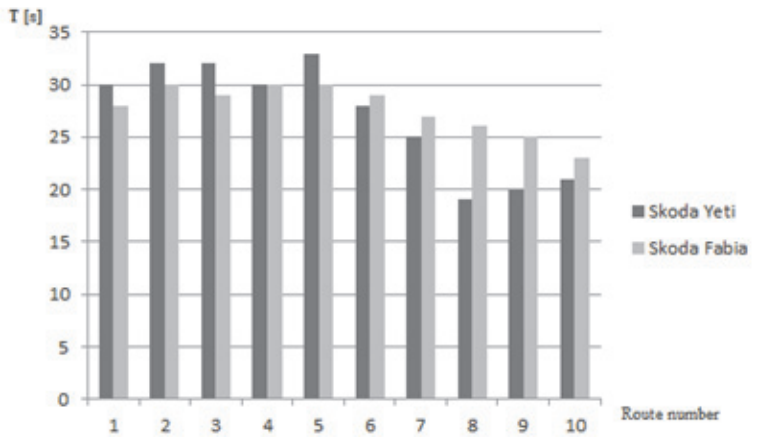
Accelerating	
	• The right hand is always on the handle of the acceleration/brake lever. Acceleration is done by turning the handle clockwise.
	• First, one needs to activate the device using the button mounted under the steering wheel. When the accelerator is set to drive, to acceleration, rotate the movable part of the ring using a natural up/down movement with a right or left hand. The force with which we rotate the moving part of the ring affects the acceleration force of the vehicle.
Braking	
	• The brake lever is located at the height of the gearbox. The braking process is carried out by pressing the lever slightly forward. The device also has a button that allows to lock the brakes effortlessly. This function is intended to support the driver when changing the automatic transmission mode and when parking on hills (braking without using the handbrake).

- The brake lever is located at the height of the steering wheel on the right hand side. To start the braking process, move the right hand on the steering wheel to the brake lever. The braking process is carried out by slightly pressing the brake lever forward in the direction of travel of the vehicle.

Source: Own study

In order to analyze the presented research problem, the previously described exercise "slalom test" was performed. The observation was recorded in the form of a video recording. The case study focused mainly on how to use the car's adaptation. From the point of view of the observation, it was the way of using the adaptive devices and the precision of the journey that was important, not the time. The described times of individual journeys are for illustrative purposes (Table 11).

Table 11. Journey times

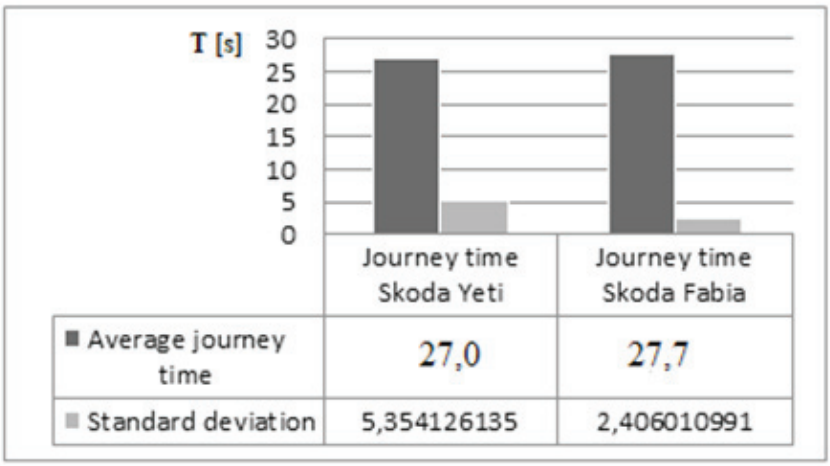


Record of travel times										
Route number	!1	22	33	44	55	66	77	88	99	110
Journey time Skoda Yeti	330 s	332 s	332 s	330 s	333 s	228 s	225 s	119 s	220 s	221 s
Journey time Skoda Fabia	228 s	330 s	229 s	330 s	330 s	229 s	227 s	226 s	225 s	223 s

Source: Own study

The number of attempts in both cases was 10 runs (N=10). The collected data show that the time needed to perform the exercise using the two adaptation sets was similar. The driver set the fastest lap time on the 8th attempt (Skoda Yeti), and the average lap time of a car equipped with a throttle/brake lever is = 27,0 seconds. The average deviation from the average travel time of the Skoda Yeti is s » 5.4 seconds. The average travel time for a car equipped with a Ghost rim is » 27,7 seconds.

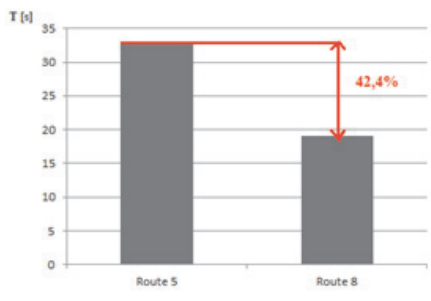
Table 12. Average journey time and standard deviation



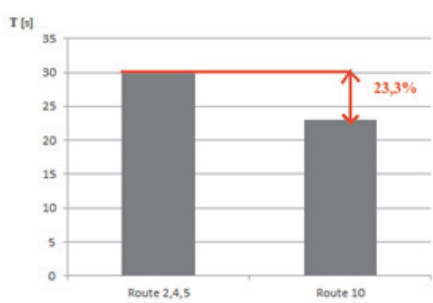
Source: Own study

The correctness of the technique of accelerating and braking increased with the number of runs. The difference between the fastest and slowest pass for a given adaptive device shows the level of driver assimilation. A larger travel time interval was observed in the case of the device installed in the Skoda Yeti » 42,4% [Table 13].

Table 13. Skoda Yeti and Skoda Fabia travel time spread comparison



Skoda Yeti



Skoda Fabia

Source: Own study

A driver who uses a rim-type device on a daily basis took part in the tests. Assimilation with a Ghost device naturally. The driver did not experience any increased discomfort resulting from the need to use this type of device. On average, the lap times differed by only ≈2.4 seconds. The technique of operating the steering wheel was similar to the standard one used by able-bodied people. The method of acceleration and braking was natural for the vehicle driver and did not require additional assimilation. The runs were carried out smoothly. During subsequent runs, the manoeuvres also became more precise, which could be noticed during the last two runs, which can be related to getting used to the vehicle and the equipment installed in it.

In the case of the set of devices installed in the second vehicle (knob and acceleration/brake lever), the first runs were performed in a less precise manner. The average travel time was similar, and the differences in the time of individual attempts in relation to the average were twice as long as in the case of the first device. The vehicle driver felt discomfort resulting from the need to use new types of adaptations, which he reported during the observation. Assimilation with the devices used increased in direct proportion to the number of test runs performed. The driver naturally adapted to the Ghost adaptive device faster than the other solution. The observed phenomenon resulted from the fact that this type of devices were the first of this group of adaptations for the driver. The driver's adaptation process in the case of the steering wheel knob and gas/brake lever set was longer. During the initial runs, the driver had trouble finding a position to operate the knob located on the steering wheel. The way of applying the acceleration and braking was also a kind of discomfort for the driver. It happened that the driver of the vehicle, at the initial stage of observation, confused the method of applying the acceleration with the braking process.

Conclusions

During the observation, the vehicle driver made all 10 runs on each of the test vehicles. The times of the individual journeys were comparable. There was no significant time difference between the individual trials, taking into account the type of adaptation used. The car adaptation chosen by the driver does not affect the manoeuvre time. Information on the time needed by the driver to perform the manoeuvre is important from the point of view of an emergency situation on the road.

In accordance with the instructions given to the driver by the person conducting the test, the „slalom test" exercise was performed correctly and in accordance with the adopted assumptions. Due to the weather conditions (moderate sunlight, dry surface), no additional factors were observed that could disturb the observations and increase the difficulty of performing manoeuvers (snowfall, slippery surface).

However, taking the right position behind the steering wheel turned out to be problematic. The difficulty in adjusting the seat to the needs of the driver, who is a person of short stature, resulted in limited visibility. Difficulties resulting from the problem of adjusting the height of the driver's seat despite the use of additional support resulted in several collisions with cones during runs in one of the vehicles. Subsequent trials carried out as part of the observation resulted in an increase in assimilation with the set of adaptive devices used in the research.

The adaptation used may cause to feel tired faster during long journeys. The choice of adaptation affects the speed of assimilation of the vehicle driver with the device. The choice of adaptation does not affect the speed of the manoeuvre. The driver quickly adapted to the adaptation set, whose method of operation is similar to the adaptation he uses privately. A subject using a device from a certain group experiences difficulties in using a new group of adaptive devices.

Difficulties in using new devices result directly from existing habits. The method of selecting appropriate adaptive devices is an individual matter. The lack of locations where the driver could test new adaptive devices means that he only uses those he knows, and new solutions cause him discomfort. In order to confirm the validity of the conclusions drawn, a research study should be carried out on a larger group of drivers. Developing driving techniques for an adapted vehicle would satisfy a wide group of users. The lack of specialized training in the technique of driving vehicles equipped with adaptations to the needs of people with disabilities means that the way they are used is an individual matter resulting from the driver's habits.

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