



## Research article

## Inappropriate driving behavior exhibited by drivers with the tendency of developmental disabilities

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## ABSTRACT

The purpose of this study was to clarify what kind of driving behavior that attributes from the disabilities is troublesome for drivers with developmental disabilities, what driving actions they are aware of as being hard to deal with, and what near-miss incidents and accidents they have experienced. This paper is composed of three studies. Study 1 is the observation of driving behavior of drivers with developmental disabilities on public roads. Study 2 is the interview survey on drivers with developmental disabilities. Study 3 is the interview survey on family members of drivers with developmental disabilities.

It is confirmed that in Survey 1 “stopping the car just before the entrance of a busy parking lot of a store” and “driving too much on the right or left side, but not at the center of the lane” are some of the characteristics of drivers with developmental disorder, in Survey 2 more than half the survey subjects feel anxiety about “right turn at an intersection without a green allow signal”, “merging and changing lanes” and “placing a car in the garage”. When asking about inappropriate behaviors of the drivers with developmental disorder to the family members who are also specialists of developmental disorder in Survey 3, more than half of them brought up the issues including “having narrow field of alert vision and not aware of his/her surroundings”, “driving without predicting what is going to happen”, “not good at doing more than one thing at the same time”, and “easily getting distracted by any movement and noise in his/her surroundings”.

## 1. Introduction

Recently, the term “developmental disabilities” has been much talked about in mass media, becoming well known to the public. The survey conducted by the Ministry of Education, Culture, Sports, Science and Technology in 2012 found that 6.5% of all children enrolled in regular class showed the tendency of developmental disabilities (including those cases where a child may not be diagnosed as developmental disability by medical institution but is considered by the teacher that educational consideration for the child study and behavior is required) [1]. However, this survey result is considered just as the tip of the iceberg, since even greater number of children may have the tendency of developmental disabilities.

There are no reports clarifying the percentage of adult population with the tendency of developmental disabilities. Although the tendency of developmental disabilities becomes less obvious as a person grows up, it is not curable. Therefore, it is speculated that the percentage of adult population having developmental disability is almost the same as that of

children. Since the establishment of the Act on Support for Persons with Developmental Disabilities in 2005, the number of people who are diagnosed as developmental disability has increased year-by-year. However, there are still numerous cases where the patients are unaware of their disabilities or have not been diagnosed despite the difficulties they encounter in daily life. Thus, in reality, the actual situation has not been perceived accurately.

Typically, adulthood developmental disorders may be divided into ADHD and autistic spectrum disorder (ASD). ADHD is a behavioral disorder characterized by “inattention” (inability to concentrate on an activity, predisposition to distraction, tendency to lose things, inability to engage in an activity in an orderly manner, etc.) and “hyperactivity/impulsivity” (inability to stay still, difficulty in waiting, interrupting/disrupting other people’s activities, etc.) [2]. In general, symptoms of ADHD appear in various forms depending on the age of the patient and the environmental condition [3]. While the hyperactive tendency may decrease as the patient reaches adolescence, the symptoms of inattention and impulsivity tend to stay longer, which is considered to last for the rest

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of the patient's life while changing forms [4]. ASD is mainly characterized with "difficulties in social communication and social interaction" and "repetitive behavior and narrow curiosity and interest" [2]. Another characteristic of ASD patients may be higher probability of feeling anxiety and fear in a non-threatening environment compared to the people with typical development [5, 6, 7]. Also, in many cases, ASD patients suffer from sensory abnormalities where they feel some light which is generally considered moderate, too bright [8, 9].

It is said that the people with the tendency of developmental disabilities are more prone to having accidents and injuries compared to those having typical development [10, 11, 12, 13]. In the interview survey conducted by Mizuno [14] on the parents/guardians of children with the tendency of ADHD, all of them revealed that their children have had experiences of being almost run over by car or bicycle, running into the road impulsively, and/or starting to run by breaking free from the parent's hand. Moreover, in the survey conducted by Clancy, Rucklidge & Owen [15], which compares children of the age between thirteen and seventeen diagnosed as ADHD with those with typical development, it was found that the children with ADHD do not only have less awareness of safety, but they also get injured by bumping into people around them twice as much compared to the children with typical development.

Furthermore, it is confirmed in the survey conducted by Woodward, Fergusson & Horwood [16] on university students between the age of eighteen and twenty-one that the people with ADHD are not only more prone to having traffic accidents, but they are also more likely to continue violating traffic rules when driving, resulting in problems such as revocation of driver's license. In addition, the in-depth study on the behavioral characteristics of people who frequently have traffic accident conducted by Sasaki, Matsumoto, Fujise, Hamamoto, Deshimaru & Ikeda [17] confirmed that the people who frequently have traffic accidents tend to have the tendency of developmental disabilities. Moreover, in a meta-analysis study that compared the traffic accident occurrence rates between the people with typical development and ADHD, it was found that the traffic accident occurrence rate for the people with ADHD is significantly higher than for those with typical development [18].

With regard to driving vehicles, it has been found that the people with ADHD, compared with the people with typical development, has a higher percentage of (1) collision with other vehicles as a result of unstable steering [19, 20], (2) entering a road in an inappropriate timing [21], and (3) colliding with an obstacle that comes in sight unexpectedly from surroundings [22]. Reimer et al. [23] has confirmed that the people with ADHD are prone to distraction in the absence of stimulus, such as on a highway, and to have difficulty attending to driving while engaging in an activity other than driving (in this case, talking on the cell phone). Similarly, young people with ADHD demonstrate a higher tendency to be distracted while driving compared with young people with typical development [24].

It has been confirmed that the people with autistic spectrum disorder (ASD) are also prone to traffic accidents as well as other issues related to driving, such as intentional violation of traffic laws and making errors, compared with the people with typical development [25]. Under more complicated driving conditions, the people with ASD have slower reaction when entering an intersection with a traffic light that is about to change [26], and take longer to find pedestrians entering the intersection [27].

It is said that developmental coordination disorder (DCD) is likely to coexist alongside with ADHD and/or ASD [2]. In addition, it has been confirmed that the people with DCD have difficulty in steering for making a curve turn and reacting to pedestrians [28].

Driving vehicles safely would help enable us to get an education, work, receive medical care, and connect with the society. For the people with developmental disorder as well, driving could improve the chance of getting employed, establishing meaningful human relationships, and becoming independent [13]. Especially for the people with developmental disorder living in areas with insufficient provision of public transportation, it would be inevitable to depend on their family members

and/or friends unless they can drive by themselves. Therefore, many people with developmental disorder desire to drive in order to establish an independent lifestyle [29]. In the meantime, the percentage of the people with developmental disorder having a driver's license is lower compared with the people with typical development [29], and it takes longer to pass a road driving test and receive a driver's license [30, 31]. In addition, it has been confirmed that the people with developmental disorder have lower confidence in their driving skills even after obtaining a driver's license [26], and young drivers with developmental disorder are suffering from cognitive damage due to accumulation of issues related to their driving experiences [23]. It is desirable in the future that the people with developmental disorder are provided with appropriate support according to the characteristics of their disorder when and after obtaining their driver's license in order to give them the same level of confidence as the people with typical development, and to enable them to live an independent life.

To make that possible, there is a need to find out what driving behaviors the drivers with the tendency of developmental disorders (drivers with developmental disorder) are prone to have when driving on public roads, what kind of awkwardness they may find in their driving behavior, what driving actions they may feel they are not good at, what type of near-miss incidents or accidents they have had. Although some inappropriate driving behaviors of drivers with developmental disorder have been confirmed, they come from findings in studies using interview surveys and questionnaires to the drivers and their family members, as well as driving simulators, but not in observation using actual vehicles on public roads.

Since a driving simulator can only create conceivable problems under predetermined situations, it is possible that some problems attributable to developmental disorder, other than those demonstrated on the driving simulator, may be presented while driving on public roads. Moreover, the inappropriate driving behaviors of the drivers with developmental disorder are considered as not only directly causing accidents, but also an accumulation of small problems in daily life. Therefore, it is necessary to understand comprehensively from a more realistic perspective what kind of problems the drivers with developmental disorder are suffering from when driving.

This study consists of three separate surveys. In Survey 1, occurrence frequency of problematic driving behaviors observed on public roads, shall be compared between drivers with developmental disorder and drivers with typical development to identify possible problem characteristics of drivers with developmental disorder. In Survey 2, interview surveys shall be conducted for drivers with developmental disorder to find out some problems they may be aware of by themselves. In Survey 3, interview surveys shall be conducted for specialists of developmental disorder who happen to be family members of the drivers to ask what they witnessed as inappropriate driving behaviors while riding with drivers with developmental disorder. By examining those three surveys comprehensively, possible driving behavioral problems attributable to developmental disorder presented in real driving shall be found out.

In previous studies, research on ADHD and ASD characteristics were performed separately, although many patients are diagnosed as either ADHD or ASD while they actually have both disorders, or sometimes patients may not be aware of their disorders [32, 33]. Therefore, in this study, patients are not distinguished as either ADHD or ASD, but instead, they are recognized as people with tendency of developmental disorders.

## 2. The observation of driving behavior of drivers with developmental disabilities on public roads (Survey 1)

### 2.1. Purpose

The purpose of this Survey is to find out what behaviors the drivers with developmental disabilities, who drive on a daily basis, would have on public road, private roads, and parking.

## 2.2. Method

### 2.2.1. Survey subjects

The survey subjects include thirty-one drivers with developmental disabilities who drive once a week or more, and ten drivers without the tendency of developmental disabilities (“drivers with typical development”). In order to exclude beginner drivers who are not used to driving from the survey subjects, the subjects are defined as drivers who have maintained the driver’s license for three years or longer. The years of experience as a driver are 13.9 ( $\pm 12.3$ ) and 14.4 ( $\pm 13.4$ ) for drivers with developmental disabilities and drivers with typical development, respectively. The drivers with developmental disorder include not only those who have been medically diagnosed as developmental disorder, but also those who are self-aware of their applicability to the diagnostic criteria for either ADHD or ASD of DSM-5 [2] without receiving medical diagnosis.

### 2.2.2. Survey method

Snowball sampling is used to recruit survey participants. The drivers are asked to drive within an area that they routinely drive, using a car that they use on a daily basis in order to eliminate a condition that they drive in unfamiliar environment. The duration of the time per survey subject is 1 h/session. A surveyor takes a back seat while a driver with developmental disabilities is driving and gives directions as to which route to take as well as observes the driver’s driving behavior. A camera is installed so that the views of forward direction and of the driver’s eyes can be recorded in a vehicle traveling data recorder simultaneously. The focuses of the observation include right turn at an intersection with no green arrow signal, right and left turns at an intersection with no traffic light, lane changing, driving on a narrow road, driving in a tunnel (including underpass), parking in a shopping mall parking lot, and pulling over to the side of the road.

No comments on the driver’s driving behavior are made while they were driving. Drivers were asked, after they exit the car, about the reasons for the inappropriate driving behaviors observed while they were driving and how they acknowledged their inappropriate driving behavior while reviewing the video image recorded on the vehicle traveling data recorder. The survey period was between September of 2019 and November of 2021.

The intent of this survey is explained to the drivers, and they were asked to drive in the same manner as usual with the same driving behavior. A consent of the drivers has been obtained about recording their driving behavior on a vehicle traveling data recorder when conducting the survey. In addition, in order to relieve the tension that the survey subject may feel due to a presence of the surveyor, an attempt is made for rapport building by having a small talk for about 15 min before starting the survey. The initiative is given to the survey subject as to the timing of departure.

This survey was conducted after obtaining the approval of the Ethics Committee of the University of Tsukuba Faculty of Medicine (Approval number: 1441).

### 2.3. Result and consideration

The inappropriate driving behaviors observed in driving on public roads, private roads, and parking were listed in Table 1. Generally, the percentage of drivers with typical development exhibiting inappropriate driving behavior is very small. Most of the inappropriate driving behaviors are observed only in drivers with developmental disabilities. The result of the Fisher’s exact test demonstrates statistically significant differences in the following four items ( $p < .05$ ): “A driver stops the car just before the entrance of a busy parking lot of a store”, “A driver has trouble making a right turn as it is hard to estimate the speed and the distance of the car coming from the opposite direction”, “A driver fails to and only pretends to check the surroundings when making a right/left turn”, and “A driver drives too much on the right or left side, but not at the center of

the lane”, implicating that these behaviors may be characteristics of drivers with developmental disorder.

After the survey, the survey subjects were asked about awareness of their behavior, “A driver stops the car just before the entrance of a busy parking lot of a store” (Table 2). More than half of the survey subjects answered that they were “not aware that they were driving inappropriately”. Their reasons include; “I have never been aware that I was driving inappropriately because that was not taught in the driving school”, and “It is a violation of the traffic law to park a car in front of the entrance, but it is not a violation to stop a car in front of the entrance; therefore, I did not think my behavior was inappropriate”. These drivers do not envision in the first place that stopping a car just before the entrance of a parking lot could become a nuisance to other drivers, or that may cause a traffic jam. In other words, they may consciously obey the rules that they officially learned in driving school as well as that prohibited by the traffic regulations, but they may not be very good at having a perspective that his/her certain driving behavior could be a nuisance to other drivers. Moreover, among those drivers who are aware that they should not stop a car just before the entrance of a busy parking lot of a store, some of them answered; “I was concentrating only on driving, thus I did not realize it was in front of the entrance of a parking lot until I stopped while following the car in front of me” or “Since I cannot distinguish which parking lot I should or should not stop just before the entrance, I end up stopping just before the entrance of any parking lot”. This indicates that their inappropriate driving behavior may be attributed to their narrow field of alert vision, a difficulty of having forecast, and a difficulty of assessing the situation on a case-by-case basis.

With regard to the comment, “I am having trouble making a right turn as it is hard to estimate the speed and the distance of the car coming from the opposite direction” (Note that people drive on the left side of the road in Japan where the survey is conducted), all twelve survey subjects that were confirmed to have this behavior actually delayed in starting a right turn even if there was enough distance from the car coming from the opposite direction. When asked about their awareness on that point after the survey, all answered that it took time to ensure enough distance from the car coming from the opposite direction and decide it was OK to turn right. There is even a case where a driver “has trouble grasping the timing to pass a garbage truck stopping with emergency lights on, thus waits until the truck starts moving again” [34]. It is often the case that people with the tendency of developmental disabilities are not good at getting a sense of speed of a moving object in the first place.

In some cases where a driver is “failing to and only pretending to check the surroundings when making a right/left turn”, that driver “is concentrating only on finding a break of a right-to-left traffic flow when turning left from a narrow alley to a busy street, thus fails to detect a pedestrian coming from the left”, or “is concentrating only on taking the empty space found in the parking lot, thus fails to detect a vehicle coming from the right at the intersection, to a near collision”. Although no significant differences are recognized, there are some cases where a driver is “failing to detect or failing to detect in time a pedestrian walking on the side of the roadway”, that driver “fails to reduce speed and/or leave space between his vehicle and a bicycle when passing a bicycle traveling on the side of the roadway”. When asked, after exiting a vehicle, why he/she did not leave space or reduce speed, the driver answered, “I did not detect the bicycle traveling on the side of the roadway when driving”. It is fair to say from the above that a high percentage of drivers with developmental disorder are unable to pay attention to pedestrians and other vehicles.

All ten survey subjects that were confirmed to “drive too much on the right or left side, but not at the center of the lane” had no self-awareness until it was later pointed out. Moreover, seven survey subjects (70%) said that “Since there are no markers on the vehicle or on the road, I have no clue to find the center of the lane for driving.

Although no significant differences were recognized, there were inappropriate driving behaviors including; a driver “is unable to stop to the right side of the lane so as not to block the traffic while waiting for the

**Table 1.** Inappropriate driving behaviors observed while driving on the public road.

|   | drivers with developmental disabilities (n = 31) |     | drivers with typical development (n = 10) |     | p value: Fisher's exact test |
|---|--|-----|---|-----|------------------------------|
|   | n  | %   | n   | %   |                              |
| A driver stops the car just before the entrance of a busy parking lot of a store  | 16   | 52% | 1   | 10% | 0.022*                       |
| A driver has trouble making a right turn as it is hard to estimate the speed and the distance of the car coming from the opposite direction   | 12   | 39% | 0   | 0   | 0.018*                       |
| A driver fails to and only pretends to check the surroundings when making a right/left turn   | 10   | 32% | 0   | 0   | 0.040*                       |
| A driver drives too much on the right or left side, but not in the center of the lane   | 10   | 32% | 0   | 0   | 0.040*                       |
| A driver fails to give a turning signal in time   | 9  | 29% | 1   | 10% | 0.219                        |
| A driver overlooks a stop sign  | 9  | 29% | 0   | 0   | 0.058                        |
| A driver fails to fully check the surroundings when changing lanes  | 9  | 29% | 0   | 0   | 0.058                        |
| A driver fails to detect a pedestrian trying to cross the street at a crosswalk with no traffic light   | 9  | 29% | 0   | 0   | 0.058                        |
| A driver tends to neglect forward checking when talking with a passenger  | 9  | 29% | 0   | 0   | 0.058                        |
| A driver fails to detect a turning signal given by a driver travelling on the next lane   | 8  | 26% | 0   | 0   | 0.083                        |
| A driver fails to detect a pedestrian crossing at the crosswalk when turning right/left   | 8  | 26% | 0   | 0   | 0.083                        |
| A driver is unable to stop at the right side of the lane so as not to block the traffic while waiting for the timing to make a right turn at an intersection with no right-turn lane      | 8  | 26% | 0   | 0   | 0.083                        |
| A driver is unable to pass the vehicle coming from the opposite direction on a narrow street with no center line due to inability to judge the width of the other vehicle                 | 8  | 26% | 0   | 0   | 0.083                        |
| A driver has trouble knowing the timing of passing a bicycle or motorbike as it is hard to know the sense of distance from the car coming from the opposite direction on a narrow roadway | 8  | 26% | 0   | 0   | 0.083                        |
| A driver fails to detect or fails to detect in time a pedestrian walking on the side of the roadway   | 7  | 23% | 0   | 0   | 0.117                        |
| A driver is unable to pull over when stopping at a kiosk or on the roadside   | 7  | 23% | 0   | 0   | 0.117                        |
| A driver forgets to turn on the light in a tunnel and/or forgets to turn off the light after exiting a tunnel   | 6  | 19% | 2   | 20% | 0.642                        |
| A driver drives too fast on a narrow street   | 6  | 19% | 1   | 10% | 0.445                        |
| A driver follows a vehicle in front on a busy street and ends up stopping in the middle of the intersection or on the crosswalk   | 6  | 19% | 0   | 0   | 0.164                        |
| A driver forgets to turn on or off the turning signal   | 6  | 19% | 0   | 0   | 0.164                        |
| A driver's let go of the brake pedal while stopping at a tollbooth or red light allowing the car to move by inches  | 6  | 19% | 0   | 0   | 0.164                        |
| A driver delays in pressing the brake pedal, ending up in hard braking  | 6  | 19% | 0   | 0   | 0.164                        |
| A driver feels strong frustration against other drivers having inappropriate driving behavior   | 6  | 19% | 0   | 0   | 0.164                        |
| A driver neglects forward checking while concentrating too much on the scenery and pedestrians  | 5  | 16% | 0   | 0   | 0.227                        |
| A driver fails to notice the traffic light changing   | 3  | 10% | 0   | 0   | 0.422                        |
| A driver starts to think about doing something unnecessary for driving while they are still driving   | 3  | 10% | 0   | 0   | 0.422                        |
| A driver presses the gas pedal before the light turns green   | 2  | 6%  | 0   | 0   | 0.567                        |
| A driver forces himself to pass a car in front  | 2  | 6%  | 0   | 0   | 0.567                        |

timing to make a right turn at an intersection with no right-turn lane” (26%) and “follows a vehicle in front on a busy street and ends up stopping in the middle of the intersection or on the crosswalk” (19%). It is noteworthy that the drivers who “follow a vehicle in front on a busy street and ends up stopping in the middle of the intersection or on the

crosswalk” answered that they misjudge the situation and “thought it was possible to follow the car in front and complete crossing the intersection”. In other words, it is speculated that their cluelessness about judging the situation and making forecasts may result in this kind of behavior. In addition, there is a case where a driver’s cluelessness about making

**Table 2.** Awareness of “Stopping the car just before the entrance of a busy parking lot of a store” (n = 16).

|  | n | %   |
|--|---|-----|
| I was not aware that I was driving inappropriately   | 9 | 56% |
| Has never been aware that it was inappropriate because it was not taught at driving school   | 5 | 31% |
| Did not think it was inappropriate because it is a violation of the traffic law to park a car in front of the entrance, but it is not a violation to stop a car in front of the entrance | 4 | 25% |
| I was concentrating only on driving and I did not realize I was in front of the entrance of a parking lot until I stopped while following the car in front of me                         | 4 | 25% |
| Since I cannot distinguish which parking lot I can or should not stop just before the entrance, I end up stopping just before the entrance of any parking lot                            | 2 | 13% |

forecasts made him “assume the car, which was actually parked on the left lane, was waiting for a traffic light, thus wait for a while behind that car”.

Some drivers demonstrate a “tendency of neglecting forward checking when talking with a passenger” (29%). More specifically, there was a case where a driver “entered an intersection with red light while being caught up in conversation with a passenger”. In another case, “a driver’s foot on the brake pedal became loose while stopping at a tollbooth or red light allowing the car to move by inches” (19%). These behaviors are caused by being distracted by one thing, disabling to pay attention to other things. Especially, when they concentrate on making payment at a tollbooth, they tend to let go of the brake pedal, resulting in the car starting to move by inches.

There are some drivers who engage in impulsive behaviors, such as “starting to think about doing something unnecessary for driving while they are still driving” (10%), “pressing the gas pedal before the light turns green” (6%), and “forcing himself to pass a car in front” (6%). For instance, there are some cases where a driver “tries to look at the cell-phone when he hears the ring tone while driving” and “take the hands off the wheel and starts cleaning the glasses as soon as he gets disturbed by fogged glasses”. When asking the reasons why a driver presses the gas pedal before the light turns green or why a driver forces himself to pass a car in front, their answers are; “I am not necessarily in a hurry, but I feel uneasy about not going fast” and “I get irritated to look at slow drivers, and I feel an urge to pass those vehicles”.

There are some drivers who “fail to follow the directions as to which route to take, that results in increased tension to trigger inappropriate driving behavior (5 drivers: 16%, while on the contrary 0 drivers with typical development have this behavior). Examples of failing to follow the directions include the following: a driver “makes a right turn at the first traffic light when directed to make a right turn at the second traffic light” and “makes a left turn when directed to make a right turn”. As a result of their failure, a driver ends up “ignoring a one-way sign and driving the wrong way” and “feeling pressured and driving over a curb repeatedly”. It has been confirmed that the people with the tendency of developmental disabilities sometimes lose a sense of self-composure because of a single mistake, and as a consequence, make other mistakes one after the other [35]. This happens in daily life as well as in driving. A lost sense of self-composure by a failure to follow a direction may lead to those inappropriate driving behaviors.

### 3. Interview survey on drivers with developmental disabilities (Survey 2)

#### 3.1. Purpose

The purpose of this interview survey is to find out perception of the drivers with developmental disabilities who drives on a daily basis as to how some of their inappropriate driving behaviors are attributed to the

characteristics of disabilities. The drivers with developmental disorder include not only those who have been medically diagnosed as developmental disorder, but also those who are self-aware of their applicability to the diagnostic criteria for either ADHD or ASD of DSM-5 [2] without receiving medical diagnosis.

#### 3.2. Method

##### 3.2.1. Survey subjects

The survey subjects recruited in snowball sampling includes forty-one drivers with developmental disabilities who drive once a week or more with a driver’s license which three years or more have elapsed since first obtained.

##### 3.2.2. Survey method

A semi-structured interview is given to the drivers individually. The survey subjects are asked about the characteristics attributable to developmental disabilities that they are conscious of in daily life (such as obsessiveness, abnormalities in sensation, difficulties of multitasking, impulsiveness, hyperactivity, carelessness, strong anxious tendency). They are also asked whether they have ever had traffic accidents or near-miss incidents, as well as the situation and the cause of the incident. In addition, they are asked about any driving operation they acknowledge as difficult to perform. The survey period was from May of 2019 and November of 2021. This survey was conducted after obtaining the approval of the Ethics Committee of the University of Tsukuba Faculty of Medicine (Approval number: 1441).

#### 3.3. Result and consideration

What situations or circumstances do drivers with developmental disabilities feel anxious about their driving, and what are the causes of the anxiety? Their answers in the interview are listed in Table 3. As seen in this table, the highest percentage of the drivers feel anxious “when making a right turn at an intersection with no green arrow signal” (71%). Among those, the highest percentage of the drivers states as a cause that “it is difficult to judge the timing of turning because of different speed of vehicles coming from the opposite direction” (61%). One of the drivers who gave this answer states that “I follow a suggestion given by my family member and judge the timing of turning with a certain object near an intersection as a clue to decide whether to go or to wait (i.e., if the vehicle coming from the opposite direction is farther than the object, then I can go ahead and make a turn). But it is difficult for me to apply this to another situation. I am unable to make a right turn at an unfamiliar intersection by myself unless some signal is given by a passenger”. That is to say, it may be difficult for some drivers with developmental disabilities, even if they drive routinely, to judge from the speed and the distance of a vehicle coming from the opposite direction whether it is safe to make a right turn unless there is a specific clue or object. It is also difficult to make a judgment by applying that clue to a different situation. Generally speaking, a driver can learn a sense of speed and distance of a vehicle coming from the opposite direction from experience, however, experiences are not good enough for drivers with developmental disabilities to deal with these situations.

Also, some drivers feel anxious about “failing to detect pedestrians on a sidewalk while concentrating on vehicles coming from the opposite direction” (46%). In other words, they have difficulties paying attention to pedestrians and vehicles coming from the opposite direction at the same time when making a right turn. Other answers include the following: a driver “gets confused as to which lane to enter where there are multiple lanes after making a right turn” (24%). This means, due to a lack of prediction for which route to take after the turn, they feel panicked with the multiple options (or lanes) suddenly presented to them. In order to avoid these adverse situations, some drivers “check all routes in advance on the internet map if it is the first time to drive in that area and remember which lane to enter”.

**Table 3.** Situations where drivers with developmental disabilities feel anxious and the causes. (Multiple counting) (n = 41)

|  | n         | %          |
|--|-----------|------------|
| <b>Making a right turn at an intersection with no green arrow signa</b>  | <b>29</b> | <b>71%</b> |
| A driver is unable to decide whether it is safe to make a right turn because of the different speed of vehicles coming from the opposite direction   | 25        | 61%        |
| A driver concentrates on vehicles coming from the opposite direction so much that he fails to detect pedestrians walking of the sidewalk   | 19        | 46%        |
| A driver gets confused as to which lane to enter where there are multiple lanes after making a right turn  | 10        | 24%        |
| A driver is unable to figure out the meaning of the flashing headlights given by a driver coming from the opposite direction   | 7         | 17%        |
| A driver is unable to judge whether to go ahead or not at the timing of the traffic light turning from yellow to red at a busy intersection with no right turn signal  | 5         | 12%        |
| <b>Merging/Changing lanes</b>  | <b>27</b> | <b>66%</b> |
| A driver is unable to judge whether it is safe to merge or to change lanes because of the different speed of vehicles coming from the opposite direction   | 23        | 56%        |
| A driver gets confused because there are too many things to do while driving, such as to check his surroundings and give a turning signal  | 22        | 54%        |
| A driver becomes nervous about rearing-ending the car in front when speeding up to merge into the highway  | 15        | 37%        |
| A driver is unable to concentrate on driving while giving flashing signal to another driver to express “thank you” after merging or changing lanes   | 13        | 32%        |
| A driver is unable to decide on his “correct” reaction when he is given a signal for merging or changing lanes by another driver   | 12        | 29%        |
| <b>Parking in a garage</b>   | <b>25</b> | <b>61%</b> |
| A driver is unable to figure out which way to turn the wheel   | 23        | 56%        |
| A driver is unsure of where to check because he needs to pay attention to many directions, including front, right/left, and back   | 18        | 44%        |
| A driver is unsure of which position to stop and how to operate the car to park the car in the garage  | 15        | 37%        |
| <b>Turning right/left into a main road at a T-intersection without a traffic light, or approaching a roadway from a parking garage</b>   | <b>18</b> | <b>44%</b> |
| A driver is unable to have a sense of speed of the vehicles traveling on the main road, thus unable to judge the timing of turning   | 15        | 37%        |
| A driver is unsure of which side (right or left) the traffic mirror is reflecting  | 13        | 32%        |
| <b>Driving on a narrow road</b>  | <b>17</b> | <b>41%</b> |
| A driver is unable to judge whether it is safe to pass by with a vehicle coming from the opposite direction  | 15        | 37%        |
| A driver is unable to have a sense of speed of a vehicle coming from the opposite direction, thus unable to judge whether it is safe to pass the pedestrians and bicycles before passing by with the other vehicle | 14        | 34%        |
| <b>Driving on an unfamiliar road under unfamiliar circumstances</b>  | <b>13</b> | <b>32%</b> |
| A driver feels nervous when driving on an unfamiliar road, making him unable to make appropriate judgment of the situation   | 13        | 32%        |
| A driver feels panicked when encountering road constructions with reduced lanes available or a car parked on the road  | 10        | 24%        |
| <b>Driving in bad weather or at night</b>  | <b>10</b> | <b>24%</b> |
| A driver is unable to concentrate on driving while getting disturbed by the movement of windshield wiper in rain   | 8         | 20%        |
| A driver has blurred front view because of the blinding headlight of a vehicle coming from the opposite direction at night   | 6         | 15%        |

Although the percentage is not very high, some drivers “are unable to figure out the meaning of the flashing headlights given by a vehicle coming from the opposite direction” (17%). These drivers state “it is not clear whether flashing headlights is signaling to go ahead and make a turn or not to go”. Since the people with developmental disabilities have a tendency of inability to consider someone’s feelings from the context [36], it may be difficult for them to take an action by understanding the intent of another driver where multiple interpretations are possible. This driver states that it is difficult to understand not only the meaning of the flashing headlight, but also the intent of another driver who turns on the hazard light or honk.

It is confirmed that some drivers, who are not good at “parking a car in the garage” (61%) and “turning right/left into a main road at a T-intersection without a traffic light, or approaching a roadway from a

parking garage” (44%), feel it is also difficult to “figure out which way to turn the wheel” (56%) and “which side (right or left) the traffic mirror is reflecting” (32%). This demonstrates that these drivers may not perform specific operations that involve shifting vision to the left/right or back very well.

Furthermore, the anxieties some drivers have “while driving in bad weather or at night” (24%) involve “unable to concentrate on driving while getting disturbed by the movement of windshield wiper in rain” (20%) and “having blurred front view because of the blinding headlight of a vehicle coming from the opposite direction at night” (15%). Because of oxyopia that some people with developmental disabilities are suffering from, they may pay too much attention to certain visual information that the people with typical development would normally ignore or may be too sensitive to the light 8,9. That may be why some drivers with

**Table 4.** Inappropriate driving behavior of drivers with developmental disabilities in terms of how they are viewed by their family members. (Multiple counting) (n = 15)

|  | n         | %          |
|--|-----------|------------|
| <b>A driver has narrow field of alert vision and is not aware of his surroundings</b>  | <b>11</b> | <b>73%</b> |
| A driver fails to detect pedestrians walking on the sidewalk when making a right/left turn   | 9         | 60%        |
| A driver forgets to turn on the light in a tunnel and/or forgets to turn off the light after exiting a tunnel  | 9         | 60%        |
| A driver overlooks a stop sign   | 8         | 53%        |
| A driver fails to fully check the surroundings when changing lanes   | 8         | 53%        |
| A driver fails to detect a pedestrian trying to cross the street at a crosswalk with no traffic light  | 8         | 53%        |
| A driver is unaware of the traffic light turning   | 7         | 47%        |
| A driver fails to notice a signal given by another driver  | 7         | 47%        |
| A driver fails to travel with a speed aligned with the surrounding situation (the crowd of pedestrians, etc.) and the speed limit  | 5         | 33%        |
| A driver fails to detect or fails to detect in time a pedestrian walking on the side of the roadway  | 5         | 33%        |
| A driver only concentrates on observing a stop sign, thus fails to pay attention to other things   | 4         | 27%        |
| A driver fails to turn on the light when it is getting dark  | 4         | 27%        |
| <b>A driver drives without focusing on what is going to happen</b>   | <b>11</b> | <b>73%</b> |
| A driver delays in pressing the brake pedal, ending up in hard braking   | 8         | 53%        |
| A driver follows a vehicle in front on a busy street and ends up stopping in the middle of the intersection or on the crosswalk  | 6         | 40%        |
| A driver gets confused as to which lane to enter where there are multiple lanes after making a right/left turn   | 4         | 27%        |
| A driver always becomes rushed when driving since he fails to plan extra time for doing anything   | 2         | 13%        |
| <b>A driver is not good at doing more than one thing at the same time</b>  | <b>10</b> | <b>67%</b> |
| A driver feels panicked when having to do more than one thing at the same time, such as to give a turning signal while paying attention to the surrounding situations and to operate a vehicle | 8         | 53%        |
| A driver tends to neglect forward checking when talking with a passenger   | 7         | 47%        |
| A driver let go of the brake pedal while stopping at a tollbooth or red light allowing the car to move by inches   | 6         | 40%        |
| A driver feels panicked with a voice of navigation system and directions given by a passenger, or the voices do not reach the driver's ears  | 5         | 33%        |
| <b>A driver easily gets distracted by any movement and noise in his surroundings</b>   | <b>8</b>  | <b>53%</b> |
| A driver concentrates on the pedestrians and the scenery at the expense of thorough forward checking   | 7         | 47%        |
| A driver follows a pedestrian traffic light where there are separate traffic lights for pedestrians and vehicles   | 4         | 27%        |
| A driver follows the flow of traffic on the next lane with a green arrow signal while the signal for his lane is red   | 3         | 20%        |
| A driver follows a traffic light not at the first intersection, but at the next intersection   | 3         | 20%        |
| A driver is unable to concentrate on driving while getting disturbed by the movement of windshield wiper in rain   | 3         | 20%        |
| <b>A driver fails to do thorough checking</b>  | <b>7</b>  | <b>47%</b> |
| A driver forgets to turn on or off a turning signal  | 7         | 47%        |
| A driver forgets to release the parking brake before moving the car  | 5         | 33%        |
| A driver opens the door without checking the distance from the wall or the next car  | 4         | 27%        |
| A driver forgets to adjust mirrors and the seat position before driving the car and do it while driving  | 3         | 20%        |
| A driver turns off the engine without putting the shift lever in a parking position and/or putting on the parking brake  | 2         | 13%        |
| <b>A driver acts impulsively</b>   | <b>6</b>  | <b>40%</b> |
| A driver impulsively starts doing something unnecessary for driving while still driving  | 5         | 33%        |
| A driver takes off quickly   | 4         | 27%        |
| A driver backs up without checking his surroundings in a situation where he goes past the destination or where he needs to go back   | 3         | 20%        |
| A driver stops the car as soon as he feels the need of it without checking his surroundings  | 3         | 20%        |
| A driver tries to force himself to pass the car in front   | 3         | 20%        |
| A driver honks unnecessarily   | 3         | 20%        |
| A driver easily feels frustrated with other drivers' driving behavior  | 3         | 20%        |
| A driver continues the same inappropriate driving behavior even after making a mistake   | 2         | 13%        |
| <b>A driver prioritizes his own rules and is sticks to the rules he initially learned</b>  | <b>4</b>  | <b>27%</b> |
| A driver prioritizes what is important for him (such as the speed and the route, etc.) over the flow of traffic  | 4         | 27%        |
| A driver stops in the middle of the intersection as soon as the traffic light turns yellow while making a right turn   | 2         | 13%        |
| A driver interprets the traffic regulations at his own discretion and makes his own rules  | 2         | 13%        |
| <b>Others</b>  | <b>4</b>  | <b>27%</b> |
| A driver becomes confused with the gas pedal and the brake pedal when panicked   | 2         | 13%        |
| A driver experiences sleepiness while driving  | 1         | 7%         |
| A driver fails to assume an appropriate driving posture  | 1         | 7%         |

developmental disabilities are oversensitive to the movement of wind-shield wiper and bright lights.

#### 4. Interview survey on family members of drivers with developmental disabilities (Survey 3)

##### 4.1. Purpose

The purpose of this survey is to find out about inappropriate driving behaviors of drivers with developmental disabilities in terms of how they are viewed by their family members who sit on the passenger seat with a driver with developmental disabilities.

##### 4.2. Method

###### 4.2.1. Survey subjects

The survey subjects include fifteen family members of drivers with developmental disabilities. The family members are defined as those who live with a driver with developmental disorder and regularly have opportunities to ride in a car driven by that driver. The family members are also specialists, who have research achievements in developmental disorder or who are involved in clinical practice. The specialists of developmental disorder are designated as survey subject because they are eligible to evaluate what characteristics of the disorder may be causing inappropriate driving behaviors of the drivers with developmental disorder. The drivers with developmental disorder include not only those who have been medically diagnosed as developmental disorder, but also those who are self-aware of their applicability to the diagnostic criteria for either ADHD or ASD of DSM-5 [2] without receiving medical diagnosis.

###### 4.2.2. Survey method

Snowball sampling is used to recruit survey participants. A semi-structured interview is given to each family member or the survey subject individually. The survey subjects are asked about behavioral characteristics of the driver with developmental disabilities observed in daily life, any near-miss incidents in the past as well as the causes and the situations of the incident. The survey period is between May of 2019 and

December of 2021. This survey was conducted after obtaining the approval of the Ethics Committee of the University of Tsukuba Faculty of Medicine (Approval number: 1441).

##### 4.3. Result and consideration

Inappropriate driving behaviors of the driver with developmental disabilities seen from the family member’s perspective and some of the specific examples of their behavior are listed in Tables 4 and 5, respectively. As seen in Table 4, the majority of the survey subjects list as inappropriate driving behaviors as “having narrow field of alert vision and not aware of his surroundings” (73%), “driving without focusing on what’s to come” (73%), “not good at doing more than one thing at the same time” (67%), and “easily getting distracted by any movement and noise in his surroundings” (53%). Some of these behaviors are also observed in Survey 1 when the drivers are asked to drive on the public road and private road and parking, however, very few of these behaviors are pointed out by the drivers themselves when they are interviewed in Survey 2. It is evident that the drivers themselves are unaware of their inability to do these things in their driving. The answers from A to D in Table 4 represent these behaviors in question. According to the family members of the driver, these driving behaviors are not coincidental, but they are rather often seen in everyday life as well. These driving behaviors are related to fundamentals of “safe driving”, which are being aware of your surroundings, accurately judging how to respond in a given situation, and driving while predicting what is going to happen. Those inappropriate behaviors pointed out by the family members suggest that the drivers with developmental disabilities fail to achieve these expectations.

Moreover, 40% of the survey subjects answered that the drivers “act impulsively from time to time”. As seen in the examples E and F below, some episodes of not just near-miss incidents, but actual accidents caused by impulsive behavior are told by survey subjects. As seen above, impulsive behaviors would highly likely result in accidents which may even lead to a major accident. Not only the impulsiveness, but also one of the characteristics of the people with developmental disabilities, “difficulty of controlling one’s emotion” may also be considered as an

**Table 5.** Specific examples of inappropriate driving behavior.

|   |  |
|---|--|
| A | <b>[A driver has narrow field of alert vision and is not aware of his surroundings.]</b><br>A signal given by another driver often does not come into the driver’s field of vision, thus he is unable to reduce speed to allow another driver to merge or to change lanes.   |
| B | <b>[A driver drives without focusing on what’s to come.]</b><br>A driver blindly follows a vehicle in front at a busy intersection and often ends up stopping in the middle of the intersection.   |
| C | <b>[A driver is not good at doing more than one thing at the same time.]</b><br>A driver gets distracted by a conversation with a passenger, nearly hitting the center median or the curbstone.  |
| D | <b>[A driver easily gets distracted by a movement or noise in his surroundings.]</b><br>A driver tends to come closer and closer to the sidewalk as he is attracted by, for example, a walking dog, small children, or attractive women.   |
| E | <b>[A driver acts impulsively.]</b><br>When a driver notices that he has forgotten to insert a ETC (Electronic Toll Collection System on the highway) card after entering the ETC lane, he goes backward without checking his back and clashed.  |
| F | <b>[A driver acts impulsively.]</b><br>As soon as a driver finds a cake shop that he has been curious about, he abruptly stops the car in the middle of the road without pulling over and exits the car, when his vehicle is clashed by a car behind.  |
| G | <b>[A driver prioritizes his own rules, and is sticks to the rules he initially learned.]</b><br>A driver prioritizes driving in a fuel-efficient way over traveling with a flow, thus he drives by completely ignoring the traffic flow. He only drives with presumably the most fuel-efficient speed (80 km/h) in the passing lane on the highway to avoid changing speed. He does not mind at all to be tailgated or passed by another car from the left lane.            |
| H | <b>[A driver prioritizes his own rules, and is sticks to the rules he initially learned.]</b><br>A driver is so obsessed by the rule of not going ahead when the light changes from yellow to red, that he remains in the right-turn lane at a busy intersection without green arrow signal, missing many times a chance to turn.  |
| I | <b>[A driver prioritizes his own rules, and is sticks to the rules he initially learned.]</b><br>A driver learned in driving school that you should try not to press the brake pedal on the highway. He strains the meaning of that as you are not supposed to press the brake pedal on the highway no matter what. When he gets very close to the car in front while driving on the highway, he feels panicked as he is not sure if he should press the brake pedal or not. |



underlying reason for some inappropriate driving behaviors, such as “forcing oneself to pass a car in front” (20%), “honking unnecessarily” (20%), and “easily feeling frustrated with other drivers’ driving behavior” (20%).

Furthermore, as for a driver “prioritizing his own rules, and sticks to the rules he initially learned”, a driver himself may not be aware that his cognition is inappropriate, but rather, he may believe that he is driving safely complying with the traffic rules. But as seen in the examples G and H, in case of a driver traveling with a slow speed ignoring the traffic flow or staying in the lane without making a right turn when the traffic light is about to change, there is a high possibility of those behaviors causing a traffic jam or some sort of trouble. In one case, which could be more serious as seen in the example I, a driver may make an extreme generalization and interpret what he learned in driving school, “not to press the brake pedal on the highway” as “not to press the brake pedal even when the car is about to clash the vehicle in front”. In this case, the instructor in driving school should teach more concretely, saying that “a driver should not press the brake pedal immediately when driving at a high speed on the highway, but instead, press the brake pedal as necessary only after using the engine brake to reduce speed”. Generally, the people with developmental disabilities are not good at assuming the meaning of what is said by trying to read between the lines. Rather, they tend to take what is said literally. In addition, they are not good at modifying the knowledge they first learned. For that reason, it is necessary to give specific instructions without omitting any words from the beginning when giving instructions to drivers with developmental disabilities.

## 5. Conclusion

It is confirmed in Survey 1 that “stopping the car just before the entrance of a busy parking lot of a store” and “driving too much on the right or left side, but not at the center of the lane” are some of the characteristics of drivers with developmental disorder. These behaviors may not directly cause accidents, but could interrupt the traffic flow or cause troubles to other drivers. Besides, the drivers with developmental disorder are not aware of the fact that they are actually driving in such manner or that such behaviors could cause trouble. The previous studies using driving simulators only confirmed the items that could directly cause accidents, including “entering a road in an inappropriate timing” [19], “delaying in reaction to enter an intersection with already changing traffic light” [24], and “colliding with an obstacle that comes in sight unexpectedly from surroundings” [20]; and the aforementioned troubling behaviors were not presented even after interview surveys conducted with the drivers themselves as well as their family members. With these points in mind, it is fair to say that behaviors of drivers with developmental disorder include those that may not directly cause accidents, but could trouble other drivers unconsciously.

It is confirmed in Survey 2 that more than half the survey subjects feel anxiety about “right turn at an intersection without a green allow signal”, “merging and changing lanes” and “placing a car in the garage”. The common reasons are “unable to have a sense of distance and speed of the car behind or coming from the opposite direction”, “unable to pay attention to multiple directions”, and “not good at doing more than one thing at the same time”. In an experiment using the driving simulator as well, the possibility was indicated that drivers with developmental disorder are prone to be distracted from focusing on the road as cognitive demand increases, disabling them to promptly react to significant incidents [37]. Where cognitive demand increases, such as in the situations of right-turn and merging/changing lanes, they can be easily distracted from focusing on the road, which as a result might invoke their inability to “pay attention to multiple directions” and “do more than one thing at the same time”. The drivers themselves had no mention of the behaviors that could potentially cause trouble to other drivers. This also confirms their lack of self-awareness as is revealed in Survey 1.

When asking about inappropriate behaviors of the drivers with developmental disorder to the family members who are also specialists of developmental disorder in Survey 3, more than half of them brought up the issues including “having narrow field of alert vision and not aware of his/her surroundings”, “driving without predicting what is going to happen”, “not good at doing more than one thing at the same time”, and “easily getting distracted by any movement and noise in his/her surroundings”. These are also confirmed in Surveys 1 and 2, which verifies that they are not demonstrated only in the experiment, but are general tendencies. Some inappropriate driving behaviors, that are not disclosed in the experiment on a public road in Survey 1 and interviews to the drivers in Survey 2, became evident, especially in Survey 3. It is assumed that the driver might have been conscious of the accompanying observer and the vehicle traveling data recorder recording his/her driving in Survey 1 and thus managed to drive carefully so as not to be pointed out any inappropriate driving behavior during that time. It has been confirmed that drivers with developmental disorder may be able to keep attentiveness with strong stimulus, but they become distracted as stimulus weakens [21], which is considered to be the case. Based on the above, Survey 1 revealed inappropriate driving behaviors observed while the drivers with developmental disorder kept attentiveness relatively well while Surveys 2 and 3 shed lights on some weak behaviors that the drivers are aware of and inappropriate driving behaviors routinely exhibited, respectively.

This study examined the various driving practices of drivers with developmental disabilities from a practical standpoint. The purpose was to examine the driving actions they felt were challenging and identify inappropriate driving behaviors that the drivers unconsciously performed. This study’s results provide valuable information regarding drivers with developmental disorders. Furthermore, it provides a basis for necessary support appropriate to their type or level of disability in their driving practice or when renewing their driver’s license. Moreover, by specifically providing examples of inappropriate driving behavior, our study contributes to building awareness of problematic behaviors for drivers with developmental disorders and attempts to reduce them.

However, there is a limit to improving the driving skills of drivers with disabilities through experience only. It is necessary not only for the drivers, but also for the driving school instructors as well as the family members to have in-depth understanding of the driving behaviors of a specific driver, and of how some characteristics of disabilities are affecting the behavior. Based on that understanding, the drivers need to practice in a specific and step-by-step manner to overcome their weaknesses depending on each characteristic.

Not only the driver’s effort, but it is also important to communicate specific information to a driver to relieve his sense of inferiority or encourage the driver to obtain useful information. We found in Survey 2 that some drivers with developmental disabilities have a family member who suggests a certain object near an intersection set as a clue to decide whether it is safe to make a right turn. We also found some drivers who checks the traffic situation in advance on the internet. It may be difficult for drivers with developmental disabilities to apply a piece of information to a different situation, but he can at least drive with confidence in a situation with adequate information. It is confirmed in Survey 1 that a driver with developmental disabilities tends to repeat mistakes when he loses a sense of self-composure. In other words, one way for drivers with developmental disabilities to drive safely may be to keep a sense of self-composure by obtaining relevant information ahead of time.

In addition, it is important to review improvement of automated driving auxiliary features. Automated driving features are very helpful for drivers with developmental disabilities who are not good at doing more than one thing at the same time. For instance, automatic light-up system would prevent a driver from making a mistake of forgetting to turn on and off the headlight and to switch from high beam to low beam. Besides, a driver would no longer need to operate the switches while driving so he can concentrate on driving.

In this study, the clinical group with diagnosis of ADHD or ASD and the non-clinical group without the diagnosis are considered continuation, and the subjects are those who are deemed highly likely to have ADHD or ASD. There is a wide range of characteristics of the people with tendency of developmental disorders, and we hoped to understand as many problems as possible that are considered as problematic driving behaviors. It is extremely difficult to collect data by only examining the clinical group with medical diagnosis as survey subject, thus we established feasible survey subjects in this study. As such, since those who have no medical diagnosis are included as the survey subject in this study, it is not completely deniable that there may be inconsistency in the result with some studies targeting only the subjects with medical diagnosis. It will be necessary in the future to study respective clinical groups for ADHD and ASD as the survey subject.

In addition, the survey results need to be taken with discretion since there are only limited number of survey subjects. While those who have tendency of developmental disorder with no medical diagnosis are the target of the survey, it is extremely difficult to find volunteers to participate in the survey, and not possible to ensure a sufficient number of survey subjects. We will continue to study by increasing the number of survey subjects.

Furthermore, in the experiment conducted on a public road in Survey 1, the drivers are asked to drive for as long as 1 h, but only for one session. Also, the experiment was conducted under a nonroutine situation with an observer riding in a car and a vehicle traveling data recorder installed. Therefore, it is undeniable that these conditions might have affected the driver's mental status as well as their driving behaviors. In the future, multiple sessions should be set up for each driver to examine whether each session produces similar results. Furthermore, in the future, I would like to study about what kind of training is required for drivers with a specific type of developmental disabilities, and what would help the drivers with developmental disabilities to make up for a sense of inferiority in particular aspect of driving. These studies would make it possible to articulate any details of retraining given to drivers with the tendency of developmental disabilities, and to provide information related to better functions of vehicles that make up for some characteristics of developmental disabilities.

## Declarations

### Author contribution statement

Tomomi Mizuno: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Wrote the paper.

Arisa Nishidate: Performed the experiments; Analyzed and interpreted the data.

Katsumi Tokuda: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data.

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Data included in article/supp. material/referenced in article.

### Declaration of interest's statement

The authors declare no competing interests.

### Additional information

No additional information is available for this paper.

## References

- [1] Ministry of Education, Culture, Sports, Science and Technology, Survey on children with developmental disabilities who are enrolled in regular classes and require special educational support (in Japanese), 2012. [https://www.mext.go.jp/a\\_menu/shotou/tokubetu/material/\\_icsFiles/afiledfile/2012/12/10/1328729\\_01.pdf](https://www.mext.go.jp/a_menu/shotou/tokubetu/material/_icsFiles/afiledfile/2012/12/10/1328729_01.pdf). (Accessed 13 August 2022).
- [2] American Psychiatric Association, Diagnostic and Statistical Manual of Mental Disorders, 5<sup>th</sup> ed., American Psychiatric Association, 2013.
- [3] R.A. Barkley, M. Fischer, L. Smallish, K. Fletcher, The persistence of attention deficit/hyperactivity disorder, *J. Abnorm. Psychol.* 111 (2002) 279–289.
- [4] T.N. Achenbach, C.T. Howell, S.H. McConaughy, C. Stranger, Six-year predictors of problems in a national sample of children and youth: 1. Cross-informant syndromes, *J. Am. Acad. Child Adolesc. Psychiatr.* 34 (1995) 336–347.
- [5] A. Gillot, F. Furniss, A. Walter, Anxiety in high-functioning children with Autism, *Autism* 5 (2001) 277–286.
- [6] R. Vohra, S. Madhavans, U. Sambamoorthi, Comorbidity prevalence, healthcare utilization, and expenditures of Medicaid enrolled adults with autism spectrum disorders, *Autism* 21 (2016) 995–1009.
- [7] S. Bellini, Social Skill Deficits and Anxiety in high-functioning adolescents with autism spectrum disorders, *Focus on Autism and Other Developmental Disabilities* 19 (2004) 78–83.
- [8] S.K. Gara, A.G. Chhetri, M. Alrjoob, S.A.A. Abbasi, I.H. Rutkofsky, The sensory abnormalities and neuropsychopathology of autism and anxiety, *Cureus* 12 (5) (2020), e8071.
- [9] E.P. Hazen, J.L. Stornelli, J.A. O'Rourke, K. Koesterer, C.J. McDougle, Sensory symptoms in autism spectrum disorders, *Harv. Rev. Psychiatr.* 22 (2) (2014) 112–124.
- [10] D. Strauss, R. Shavelle, T.W. Anderson, A. Baumeister, External causes of death among persons with developmental disability: the effect of residential placement, *Am. J. Epidemiol.* 147 (9) (1998) 855–862.
- [11] H. Shiraiishi, T. Mizuno, Recognition and training needs of the school nurse in the support to students with developmental disorder, *Journal of Understanding Special Needs* 14 (2012) 35–42, 2012.
- [12] F. Craig, F. Margari, A.R. Legrottaglie, R. Palumbi, C. de Giambattista, L. Margari, A review of executive function deficits in autism spectrum disorder and attention-deficit/hyperactivity disorder, *Neuropsychiatric Dis. Treat.* 12 (2016) 1191–1202.
- [13] H. Bishop, L. Boe, D. Stavriou, J. Mirman, Driving among adolescents with autism spectrum disorder and attention-deficit hyperactivity disorder, *Saf. Now.* 4 (3) (2018) 40.
- [14] T. Mizuno, Education for toddler with ADHD with impulsive tendency to avoid traffic accidents and its effect, *Journal of Understanding Special Needs* 19 (2018) 1–10.
- [15] T.A. Clancy, J.J. Rucklidge, D. Owen, Road-crossing safety in virtual reality: a comparison of adolescents with and without ADHD, *J. Clin. Child Adolesc. Psychol.* 35 (2) (2006) 203–215.
- [16] L.J. Woodward, D.M. Fergusson, L.J. Horwood, Driving outcomes of young people with attention difficulties in adolescence, *J. Am. Acad. Child Adolesc. Psychiatry* 39 (2000) 627–634.
- [17] H. Sasaki, T. Matsumoto, A. Fujise, J. Hamamoto, M. Deshimaru, M. Ikeda, A case of an old adult who had repeated traffic accidents responded to the treatment for ADHD, *Jap. J. Psych. Treat.* 30 (12) (2015) 1649–1655.
- [18] L. Jerome, A. Segal, L. Habinski, What we know about ADHD and driving Risk; a literature review, *Meta-Analysis and Critique, J. Canad. Acad. Child Adolesc. Psych.* 15 (3) (2006) 105–125.
- [19] R.A. Barkley, K.R. Murphy, D. Kwasnik, Motor vehicle driving competencies and risks in teens and young adults with attention deficit hyperactivity disorder, *Pediatrics* 98 (6) (1996) 1089–1095.
- [20] E. Sobanski, D. Sabljic, B. Alm, G. Skopp, N. Kettler, R. Mattern, P. Strohbeck-Kühner, Driving-related risks and impact of methylphenidate treatment on driving in adults with attention-deficit/hyperactivity disorder (ADHD), *J. Neural. Transm.* 115 (2008) 347–356.
- [21] M.A. Nikoras, A.L. Elmore, L. Franzen, E. O'neal, J.K. Kearney, J.M. Plumert, Risky bicycling behavior among youth with and without attention-deficit hyperactivity disorder, *JCPP (J. Child Psychol. Psychiatry)* 57 (2) (2016) 141–148.
- [22] J. Biederman, R. Fried, M.C. Monuteaux, B. Reimer, J.F. Coughlin, C.B. Surman, M. Aleardi, M. Dougherty, S. Schoenfeld, T.J. Spencer, S.V. Faraone, A laboratory driving simulation for assessment of driving behavior in adults with ADHD: a controlled study, *Ann. Gen. Psychiatr.* 6 (4) (2007) 1–7.
- [23] B. Reimer, B. Mehler, L.A. D'ambrosio, R. Freid, The impact of distractions on young adult drivers with attention deficit hyperactivity disorder (ADHD), *Accid. Anal. Prev.* 42 (3) (2010) 842–851.
- [24] K.M. Kingery, M. Narad, A.A. Garner, T.N. Antonini, L. Tamm, J.N. Epstein, Extended visual glances away from the roadway are associated with ADHD-and texting-related driving performance deficits in adolescents, *J. Abnorm. Child Psychol.* 43 (6) (2014) 1175–1186.
- [25] B. Daly, E.G. Nicholls, K.E. Patrick, D.D. Brinckman, M.T. Schultheis, Driving behaviors in adults with autism spectrum disorders, *J. Autism Dev. Disord.* 44 (2014) 3119–3128.
- [26] D. Chee, H. Lee, A. Patomella, T. Falkner, Investigating the driving performance of drivers with and without autism spectrum disorders under complex driving conditions, *Disabil. Rehabil.* 41 (1) (2019) 1–8.
- [27] E. Sheppard, D. Ropar, G. Underwood, E. van Loon, Brief report: driving hazard perception in autism, *J. Autism Dev. Disord.* 40 (2010) 504–508.
- [28] R.F. de Oliveira, J.P. Wann, Driving skills of young adults with developmental coordination disorder: maintaining control and avoiding hazards, *Hum. Mov. Sci.* 31 (3) (2012) 721–729.

- [29] V. Gaylord, A. Abeson, E. Bosk, J. Timmons, S. Lazarus, Meeting transportation needs of youth adults with developmental disabilities, *Impact* 18 (2005) 1–34.
- [30] I. Takahashi, T. Onoshima, Y. Umenaga, Support and challenges in obtaining driver's licenses by individuals with developmental disorders, *The Japanese Journal of Autistic Spectrum* 18 (2) (2021) 41–49.
- [31] A.E. Curry, K.B. Metzger, M.R. Pfeiffer, M.R. Elliot, F.K. Winston, T.J. Power, Motor vehicle crash risk among adolescents and young adults with attention-deficit/hyperactivity disorder, *JAMA Pediatr.* 171 (8) (2017) 756–763.
- [32] S. Yoshimura, M. Toichi, Possible neural background of affect and emotion: from the perspective of the impairment of affect in autism spectrum disorder, *Jap. J. Neuropsych.* 34 (2018) 248–257 (in Japanese).
- [33] E. Simonoff, A. Pickles, T. Charman, S. Chandler, T. Loucas, G. Baird, Psychiatric disorders in children with autism spectrum disorders: prevalence, comorbidity, and associated factors in a population-derived sample, *J. Am. Acad. Child Adolesc.* (2008) 921–929.
- [34] F. Happe, U. Frith, The Weak coherence account: detail-focused cognitive style in autism spectrum disorder, *J. Autism Dev. Disord.* 36 (2006) 5–25.
- [35] M. Sato, Y. Kudo, Self-determination support for ASD students through work experience: through a comparison of internship and part-time work experience, *Missionalia* 4 (2019) 95–111 (in Japanese).
- [36] W. Sato, T. Kochiyama, S. Uono, S. Yoshimura, M. Toichi, Neural mechanisms underlying conscious and unconscious gaze-triggered attentional orienting in autism spectrum disorder, *Front. Hum. Neurosci.* 11 (2017) 339.
- [37] B. Reimer, R. Fried, B. Mehler, G. Joshi, A. Bolfek, K.M. Godfrey, N. Zhao, R. Goldin, J. Biederman, Brief report: examining driving behavior in young adults with high functioning autism spectrum disorders: a pilot study using a driving simulation paradigm, *J. Autism Dev. Disord.* 43 (9) (2013) 2211–2217.