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THE DEVELOPMENT OF ADAPTIVE DRIVING MODIFICATIONS FOR THE DISABLED VEHICLE: A REVIEW

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ABSTRACT

Restriction and inability to drive a vehicle are known to be the biggest factors limiting mobility, in particular for the person with disabilities. This review identifies the development of adaptive driving modifications and its use for the disabled driver in a comprehensive approach. By far, assistive aids variations have managed to improve the disabled person activity for daily living limitation. Some of the assistive aids reported manage to address the issues on mobility for the person with disability from its use. Even so, it was discovered that some of the modification used resulted with the risk of injuring the user. The discovery from this review is hoped able to help in justifying the necessities in using assistive aids, allowing the person with disabilities to drive independently. Nevertheless, important summaries and the conclusions will be presented based on the gathered data.

Keywords: Modification Development, Adaptive Driving, Disabled Vehicle, Usability, Effects

1. INTRODUCTION

Mobility for the person with disabilities is the most crucial necessities as it helps them to move from point A to their desired destination. The statement found mirror to the study conducted by Ragogna and colleagues[1], where they mention that access to a vehicle is always a crucial issue for people with disabilities (PWD) who depending on other people as helper.

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The results gained by Ragogna[1], also found to be similar to studies conducted by Fernandez [2], on people with juvenile on-set amputation driving performance. A similar situation was found proved by Ikeda et, al. [3], in their studies on highway driving between 10 disabled and 5 able-bodied respondents. As to add more to the statement, the study between 5 able-bodied and 10 disabled driver displays huge differences on accelerated velocity, and also driving load. Another study similar to Fernandez [2], and Ikeda et, al. [3], on the disabled driver driving ability was found conducted by stern [4], using STISM software. As to add more to the statement, the study led to the result where the person with disabilities performing a much lower driving consistency, and requires more time towards completing a driving task.

The vehicle ingress and aggress are also found to be the major barriers, in particular for the person with disabilities. The situation was found proved in the studies conducted by Haubert[5], and Kataoka[6]. Both studies display the result where the condition of disabilities between persons is different and, getting in and out ability influenced by the vehicle types.

Past studies have led to the discovery of adaptive modification variation for the disabled vehicle. The situation can clearly be seen in the review done by Roosmalen[7,8], and Monacelli[9].As to add more, both review on the adaptive modifications classifies the modification into categories known to be the primary control, the secondary control, foot control, and also wheelchair access. Even so, the review done by them are mostly in general and did not display any description regarding on the development and its usability effect. One of the latest reviews relating to the disabled driving was found done by Greve and colleagues [10] in 2015. As to add more to the statement, the findings from the review only emphasise on the availability of physical movement assessment and also the potential strategies to evaluate the driving abilities. As the result, none of the reviews mention any advanced modifications, making the discovery of assistive driving available to be limited and more difficult.

To the best of author knowledge, there is no comprehensive review done on the adaptive driving modification development, and the effects when in use by the person with disabilities. Therefore, this review paper was not trying to challenge any of the previous study conducted but, this paper will try to review the adaptation innovation for the disabled driver in a more comprehensive manner. It is hoped that the findings will give a more deepened insight toward the development adaptive driving, in particular for the disabled vehicle.

II. THE DEVELOPMENT OF ADAPTIVE DRIVING MODIFICATION

Some early adaptive driving modification was found in the study conducted by Shaw [11], Maisa[12], and also Sanchez [13]. As to add more, the adaptation consist of a four type of steering adaptation known to be the spinning knob, the Tri-pin, the U-grip and also the Wheel rim mounting bracket. This three studies involves the use of SLED Simulation [11], and Finite Element Analysis [12,13]. The three studies has led to a result where the adaptive modification discovered asnot suitable for disabled driver use, high risk to cause serious injuries to the driver body, and also causes interference to the air bag deployment area.

Adaptive Cruise Control or ACC was found to be another early development of the adaptive modification for disabled vehicles. Several past studies on ACC as an adaptive modification resulted with the ability to reduce the hand movement and assisting the driver safe distance by controlling the speed [14]. Studies on the use of the adaptation were found conducted by Laura [15], between two ACC features located on a different haptic degree position. As the result, ACC must be placed near to the hand reach position. Even so, modern vehicles particularly the luxury category was already installed together with ACC features.

Several adaptations for vehicle accessibility found available in the evaluation studies conducted by Linda [8]. In the evaluation, several types of adaptations were introduced such as the Rear facing wheelchair passenger system (RF-WP) with wall-side contact plate and aisle-side arm, and the four-point strap-type tie-down system. As to add more, the adaptations are mostly used in the Large Accessible Transit Vehicle (LATV).

The advancement of adaptive modifications for the disabled vehicle began to evolve in line with the technology improvement and, this scenario can be view in the findings gained in the table 1. Even so, some of the findings on development in the table 1 display inconsistent modification usability effect. As to add more, the status of several modification developments can be described as unsafe to use. The standard J1903 [16] and also J2388_201110[17] developed by the Society of the Automotive Engineers clearly highlight the aspect of safety for any modifications to be made on a vehicle. As to add more the standard encompass aspect such as the suitability of the design to the user, operation suitability and safety, and also the ability of modification to also be used by the able –bodied person.

Table1. Adaptive Driving Modifications Development and the Effect from the Usage

Authors	Adaptations	Findings
Quintin[18]	Speech Recognition	Noises disturbance from the vehicle distracts the driver recognition accuracy when performing the mentioned word of action
Peters .[19]	Joystick Control	The Joystick control became difficult when the lateral and longitudinal controls were decoupled and active feedback provided compared to the other designs. There is a need to adapt the joystick individually specifically the feedback forces.
Wada [20]	Joystick Car Drive System on Wheelchair	The system tested on a private test road since no permission received from the authorities. The conducted test drive successfully realized without any driving error or failure on the system.
Messaoudène[21]	Brake Hand Wheel Concept	Complicated manoeuvrings was easily realized when the steering Concept is used.
Murata and Yoshida [22]	Driving Interface using Gesture Operation	The semi-automatic steer control was only suitable for parking and traversing crank- ors-shaped courses.

Boyce [23]	PHC-3 portable hand control	The user is required to use the thumb to operate the accelerator.
	TNT portable hand control	The equipment ease the drivers operate controls with multiple muscle groups.
Yamashita [24]	Phantom Omni Haptic hand Control	The haptic device's input power can be adjusted to ensure safety and learning.
Klarborg[25]	Intelligent Speed Adaptations (ISA)	ISA reduced the percentage of the total distance that was driven above the speed limit. ISA suited as an assistive device rather than for training purposes.
Lakkam[26]	Kinematic Measurement Devices	A performance and a braking test computer which was used to investigate vehicle speed.
Jones [27]	Flip in flip out accelerator pedal	A two interconnected accelerator pedals positioned on the left (left foot accelerator) and right (conventional accelerator pedal). Only one pedal will function at one time.
	Organ Pedal	An accelerator pedal originating the conventional accelerator pedal position on the right. The equipment can only be used

		with "fly by wire" throttle system.
Barton [28]	Swivel Seat	The modifications are available in Manual and electric powered. The modifications are able to swivel to 90 degrees rotation.
Lawton [29]	Postural Support (Pelvic, Thoracic, and shoulder)	The postural support adaptation causes discomfort, usage difficulties and conspicuous appearances. The postural support adaptation requires the driver to stabilise or brace against something when driving.
Nilsson[30]	Brake Accelerator Pedal	The driving experience using the combined brake–accelerator pedal eliminates errors relating to the age and gender of the driver. The total number of errors decreased from 25 to1, 2=22.15, df=1, P 0.001. A conspicuous difference between male and female drivers was discernible, with the female drivers committing the majority of errors, 2 =33.33, df=1, P 0.001

III. POTENTIAL STRATEGIES FOR EFFECTIVE ADAPTIVE MODIFICATION AND USABILITY

It is almost impossible for a development of disabled vehicle adaptive modification to address multiple limitations, in particular to the person with disabilities. Moreover, the conditions of mobility limitation between persons with disabilities were different and vary. For that, the approach of implementing the virtual reality could be the most appropriate option to assess the modification reliability, in particular for the disabled driver. An example of usability evaluation effectiveness can be viewed in the studies conducted by Gamache [31], on simulator training for persons with traumatic brain injuries. As the result, the subject managed to improve the driving situation after completing the 25 training session. A similar result on the simulation training effectiveness also found conduct by Davis[32], on 11 military personnel. Both studies clearly mirror the statement as the result displays an improvement of familiarity increment on disabled vehicle driving. As to add more, the establishment of several simulation training facilities such as the DTS (Driving Test Simulator) in the United Kingdom [33], has made the situation to become much clearer and achievable.

The availability of virtual reality technologies has also led to the opportunity towards developing a more effective adaptive modification to be use on a vehicle. The situation clearly proved in the studies conducted by Nasoz[34], in developing a new adaptive car interface. As to add more to the statement, the use of virtual reality simulation will help the investigator to perform the product evaluation in many situations such as the road condition, and also the user behaviour. By right, the approach of using the virtual reality for product development also found implement in automotive design through spatial augmented reality [35], in the complex product design development stages in aerospace cases [36], and also during the complex product conceptual stages [37]. As the result, the three mentioned segment resulted with the ability to capture the user feedback during the virtual reality stages.

IV. CONCLUSION

This paper presented a comprehensive review on the development of adaptive driving modifications for the disabled vehicle. A vast number of available references show that assistive aids variously developed and address the driving limitations according to the disabled driver impairment level. Even so, most of the assistive aids found within the conducted studies known to be resulting in discomfort, and built with less safety considerations, in particular for the disabled driver. At the same time, there are still challenges towards determining the effectiveness of newly developed assistive aids, particularly to the driving condition for the person with disabilities. The effectiveness of assistive aids still requires further development as newer innovation consist a more-advanced computerized operational system. Such situation may result with unused aids flooding the market, due to the unavailable result of the modification usability. More assessment and evaluation need to be done in order to allow one product to achieve optimum standards, and suitable to be use by not only the person with disabilities, but also those, who are able-bodied. This review will hopefully spark an insight in developing the assistive aids in a wider view on modification variations, its usability, and also the driving safety approach for the user.

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