Perception of Semi-Autonomous Intelligent Vehicles Such as Smart Powered Wheelchairs

Malik Haddad[1,3], David Sanders[2,3], Giles Tewkesbury[2,3], Shikun Zhou[2,3] and Martin Langner[2,3]

[1]Northeastern University – London, St. Katharine's Way, London, U.K.
[2]Faculty of Technology, University of Portsmouth, Anglesea Road, Portsmouth, U.K.
[3]Chailey Heritage Foundation, North Chailey, Lewes, U.K.

Keywords: Smart Wheelchair, Autonomous, Semi-Autonomous, Autonomy.

Abstract: This paper investigates perceptions of what semi-autonomous vehicles such as Smart powered-wheelchairs are and whether perception has changed. Information about semi-autonomous vehicles (especially powered-wheelchairs) was analysed to investigate how concepts and their benefits are perceived. Some common understanding is found, but there is uncertainty about whether autonomous/semi-autonomous implies automatic/un-manned. There is a tendency to distinguish between semi-autonomous and un-manned but that distinction does not appear to be made in the minds of everyday people. Implications of this are discussed.

1 INTRODUCTION

Automation has been used with powered-wheelchairs since their inception (Sanders et al, 2010a; 2011a). Technological innovations have allowed many manual tasks to be automated, letting wheelchair users operate their chairs more safely and with greater efficiency (Sanders et al., 2010b, Haddad et al., 2020a). At times automation can take over completely but that is not ideal (Sanders et al., 2011b; Haddad and Sanders, 2019). Despite awareness of the matter, people don't really appear to understand what a semi-autonomous vehicle is (Eriksen, 2019).

There are barriers that put off disabled people or carers from taking up assistive mobility and technology. These include cost, difficulties procuring equipment, and lack of funding, information and understanding. The lack of understanding has led to a fear of assistive mobility and technology, a shortage of suitable support and training, unhelpful way of thinking, too little evaluation, problems overseeing equipment, and lack of resources (such as time) and other provision. This paper investigates the understanding of the terminology surrounding powered mobility, especially phrases such as semi-autonomous and autonomous.

Autonomy can be defined as "the ability to act and make decisions without being controlled by anyone else" (Hornby, Ashby and Wehmeier, 2005). So

semi-autonomy is something between a wheelchair user and an automated system being in control (Haddad et al., 2020b). An everyday view of autonomy is that it "acts and makes decisions", but that suggests a capability to engender desires and then act on them (Eriksen, 2019). A system that was completely autonomous would occasionally operate using objectives that it created so that it would be essentially un-deterministic. The more autonomy, the less controllable something is (Rødseth and Burmeister, 2012). An autonomous robot would be wholly intelligent, and therefore not completely manageable, except through negotiation. Such a system is not desirable for powered-wheelchairs as the idea is to assist a user, although it can be safer for a system to sometimes take over. So, the most a powered-wheelchair should be is semi-autonomous.

Autonomy has come to mean something else over time as words do change their meaning over time. For example, in the 1300s, artificial meant it was created artfully by a skilled craftsman (@Listverse, 2016). Problems can arise when words are not defined clearly or when a contradictory use or definition exists. That can cause problems as statements or projections may suggest to expectations that are just not realistic. It can be hard to challenge a statement when it is ambiguous.

The motivation of this paper is to explores how semi-autonomous powered-wheelchairs are defined and perceived and to explore whether that is

understood. Some supposed advantages of semi-autonomous powered-wheelchairs are also considered, along with some anticipated challenges.

2 AUTONOMOUS CONTRASTED WITH AUTOMATION

Automation refers to using a computer or machine or to do work rather than using a person (Cambridge Dictionary, 2019). Automation surrounds us. Autonomy and automation sound related but, although a house may be able to sustain a fairly continuous temperature without a human being interacting with the system once set, a house isn't autonomous. Automation and autonomy are not the same thing, but they do overlap. They can both be considered to be on a continuous scale with automation or autonomy at one end and manual processes at the other end. Modern Smart powered-wheelchairs all have some automation on-board and a semi-autonomous system requires some automation. But is how complex the level of automation is enough to decide that a system is semi-autonomous. And if that is the case then where would the dividing line be? Smart wheelchairs can start and stop without human interaction, instead the signals come from a management system. Motor control systems are becoming more complicated. Some cars have had these systems for a while, so that they are automated (but not autonomous). A Nissan engineer, said "a truly autonomous car would be one where you request it to take you to work and it decides to go to the beach instead" (Eriksen, 2019).

The term semi-autonomous car usually refers to a car in which some of the driving function(s) might be automated (or partially automated). An autonomous car is self-driving. That also appears to apply to Smart wheelchairs, but the matter of self-driving becomes problematic there. A human user controls a wheelchair's heading but sensor systems can sometimes adjust that control, for example to avoid an obstacle. Other wheelchairs follow tracks laid out on or under the ground and automatically change course at junctions. Powered-wheelchairs with dynamic positioning systems go further and might conduct precise movements without specific instructions from their drivers. If the dividing line between non- autonomous, semi-autonomous and autonomous is self-driving, then a missing instance might just be the capacity to perceive and then plan ahead to avoid other powered-wheelchairs. That is to use Global path planning rather than obstacle avoidance.

In short, definitions of autonomy that can be found within dictionaries do not mean the sort of autonomy found within vehicles. Automation is needed to provide some level of autonomy, but even complicated automation is not in autonomous. Self-driving might be required but will only ever be a fraction of the whole answer.

3 METHOD

Material used for research described in this paper was mainly gathered through literature searches, but was supported by more focused questionnaires and interviews. The research focused on that way in which phrases and words were used in speech and writing, and how people generally described the theme. The research considered how knowledgeable readers might expect to understand the words. That was subjective though and another reader might form a different understanding depending on their attitude, focus and knowledge. The research tried not to interpret or extrapolate statements and not to read any pre-conception beyond that which was originally intended. Text was examined and evaluated, focusing on: How is autonomy defined, and what characterizes an autonomous or semi-autonomous vehicle? How is the term autonomy used in relation to automation? What benefits are expected from semi-autonomous vehicles? What challenges are expected during the development and operation of semi-autonomous vehicles?

This research investigated articles in conference proceedings and scientific journals. But the focus was on understanding how lay people perceived the notion of semi-autonomous vehicles, and especially powered-wheelchairs. Material with different focuses, including human nature, business, technological and legal, were incorporated to provide a broad view of perceptions of semi-autonomous powered-wheelchairs.

News stories were included although they were not considered to be completely accurate sources of scientific material. However, they did convey how "semi-autonomous" was seen by the public. Newspaper stories fed the prospects, benefits and definitions of semi-autonomous vehicles (and especially powered-wheelchairs) to the wider public and the way that they were portrayed informed their perception of the topic. The news stories were mainly extracted from online open-source magazines. Six press-releases were also incorporated. Quantitative

approaches were adopted in analysing both the news stories and the science literature. Two matrices were created, one for the news stories and one for the science literature. Some statements and phrases were common in the news stories but not within the science literature and some statements and phrases were common in the science literature but not within news stories.

Use of the term automation compared to autonomy, and semi-autonomous compared to un-manned, were assessed to decide whether there was "clear separation" between them. "No or unclear separation" meant connection was clearly implied or they were explicitly used synonymously, such as "a challenge for a semi-autonomous vehicle designed to operate safely without intervention from the driver". The analysis treated a paper or article as a single document but did search for contradictory declarations within the text. If one document talks about a benefit of semi-autonomous or -autonomous vehicles, for example, while another document presented a statement that opposed the first, then both of the views were recorded for that document. The same was the case for relationships between statements. In one news article, two sources were interviewed that each had their own take on autonomy. The first source explained "there are many perceptions of what " autonomous" actually means and whether the term refers to un-manned or manned", separating the two terms. Later, the other document stated that "in general if we compare manned and autonomous vessels, the savings for autonomous vessels is roughly 23 percent", implying that autonomous vessels are un-manned. So, both classes "no or unclear separation" and "clear separation" were recorded.

4 ANALYSIS

The material studied consisted of 23 papers, three brochures and four reports all written by twenty-one editors and authors. Research investigated potential concepts for partially autonomous powered-wheelchairs. The focus was on manned operation, but vehicles could operate semi-autonomously or automatically. A smart wheelchair must have some mechanical redundancy and requires sensors and more advanced automation than a standard powered wheelchair. The next generation of Smart wheelchairs are expected to include flexible and integrated controllers and wireless communications. Advanced decision support systems will allow powered-wheelchairs to function under semi (or sometimes

autonomous) control. Various authors have set out initial positions and rationale about developing powered-wheelchairs but the relationships between semi-autonomous, automatic, and intelligent control are blurred. Full autonomy is not desirable for a powered wheelchair; assistive technology is required rather than autonomy. A wheelchair without any constraint would be non-deterministic. That amount of autonomy, sometimes called fully autonomous (Eriksen, 2019), has been called intelligent. Rather misleadingly, intelligent is a level of autonomy that sits above semi-autonomous or autonomous (figure 1). Automatic is below autonomous on the scale of autonomy. Semi-autonomous would be somewhere in between.

Figure 1: Determinism against Autonomy in MUNIN (Rødseth & Burmeister, 2012).

A definition of autonomous control is "the ability to make complex decisions that may not be easily described through mathematical or logic formulas, but which still are constrained within certain predefined limits" (Eriksen, 2019; Rødseth & Burmeister, 2012). They explained that "most systems that claimed to have semi-autonomous control functions were mostly automatic rather than truly semi-autonomous or even intelligent" (Eriksen, 2019). The team at Portsmouth are aiming for an automatic powered-wheelchair with the ability to handle certain unplanned situations within defined constraints that can be controlled by a human user. What is often meant by autonomy can be a complicated type of automation (figure. 1), where autonomy and automation. In figure 1 they are shown on the same scale. When automation is used "it is assumed that gradual automation will step by step lead the way to truly autonomous in the future".

The terms semi-autonomous and un-manned have been defined: "A semi-autonomous powered-wheelchair navigates and takes evasive action based on an automated software system". A semi-autonomous powered-wheelchair would not really be able to operate when un-manned, and what would be the point? An un-manned powered-wheelchair would have to be more than semi-autonomous; it could

sometimes be under semi-autonomous control but it could also be remote controlled from a Control Centre, or somewhere else. This definition helps to separate the terms: a semi-autonomous powered-wheelchair needs to be manned, an un-manned powered-wheelchair is not semi-autonomous and an autonomous powered wheelchair becomes something else. In spite of that, the two terms have frequently been used interchangeably and occasionally synonymously. The use of the terms semi-autonomous and un-manned has varied, with publications and documents sometimes favouring one or sometimes the other, but regularly there is a mix of the terms used interchangeably. Un-manned has described both the operation of a vehicle and the vehicle itself as an individual object. Autonomous has described systems controlling semi-autonomous vehicles (such as wheelchairs), and the navigation or operating mode, and the individual vehicle as an object.

Benefits of semi-autonomous powered-wheelchairs include reducing carer costs, and improving safety for both the powered-wheelchair and the wheelchair user. The latter because of a reduced risk of human error. Human error has been a contributing factor or the whole cause of a lot of accidents (Eriksen, 2019). More autonomy could improve powered-wheelchair safety by partly replacing a human user with automation. By eliminating at least some of the human user in the control loop, some of the risk of harm to them and other people reduces. But that can defeat the object.

Powered-wheelchair intelligence can come from increasing the collection of data and increasing the speed and amount of processing. Increasing powered-wheelchair intelligence could optimize operation and route planning and improve management and condition monitoring of both the user and the wheelchair. The challenges in developing and operating semi-autonomous powered-wheelchairs are in achieving sufficient technical robustness and communication links.

A lack of contractual or legal frameworks around semi-autonomous powered-wheelchairs is cited, and the difficulty of transferring "powered-wheelchair sense" to a User is alluded to together with the issue of automation awareness where a driver may not be completely aware of how much the automated system is doing. A semi-autonomous powered-wheelchair needs to be under constant supervision from a user who is able to take over control or at least direct the wheelchair if required. A situation can arise that an onboard system can't deal with so that a powered-wheelchair must be able to stop safely, essentially requiring some position control (or at least a brake). More sensors, automation and mechanical redundancy are needed. Autonomous (or semi-autonomous) powered-wheelchair, is not defined anywhere. Semi-autonomous is generally used to describe a Smart wheelchair but that is used interchangeably or synonymously with intelligent and Smart.

There is a danger of skill degradation in wheelchair users if they do not experience full control of their wheelchair, especially if a semi-autonomous system is taking control some of the time and the user does not understand the cause and effect. Skill degradation or lack of learning, combined with reduced situational awareness, may be critical when a user is suddenly required to react or quickly take control. Poor automation awareness and poor situational awareness can be risky, particularly when a wheelchair user or carer is expected to monitor their own powered-wheelchair systems or other assistive systems. It may be challenging to add "safe driving" to a semi-autonomous system.

Scientific papers focused on human, commercial and legal aspects, or on developing and testing explicit technical techniques and schemes. The focus of a document had an effect on the precision of the definitions of semi-autonomous or Smart powered-wheelchairs within the document. Documents exploring wider consequences tended to be more specific. Documents describing technical systems tended to describe the systems in detail, while the general concept of powered-wheelchair autonomy was more vaguely defined and sometimes not defined at all, because it was not needed to understand the technical system(s) themselves. Smart was often used as either an overarching term that encompassed the semi-autonomous powered-wheelchair or synonymously with autonomous or semi-autonomous. There was usually a separation between terms. One example said: "note that the terms un-manned and autonomous or semi-autonomous are often interchanged, but they are not the same". There was sometimes no or unclear separation between terms, such as where manned and semi-autonomous were juxtaposed. Sometimes terms were used interchangeably. In other cases, the separation between terms was not sufficiently discussed.

The potential benefit of increased reliability for semi-autonomous powered-wheelchairs was mentioned once. Some papers mention the semi-autonomous powered-wheelchair or Smart Chair having a positive impact on users. The most frequently mentioned challenge was that legislation does not allow for semi-autonomous driving

outdoors. The man-machine interface for semi-autonomous powered-wheelchairs was mentioned as problematic in many papers. They tended to concentrate on bespoke input devices. Some papers stated that the cost of building a semi-autonomous powered-wheelchair is higher than for a standard powered-wheelchair, while only one expected it might be less. Public perception of semi-autonomous powered-wheelchairs as being a little unsafe was mentioned in connection with mobility scooters being used on public roads

News stories contained statements, opinions and views from many sources. Their shortness did not allow complete and in-depth coverage or for detailed definitions. Journalists sometimes may have quoted things out-of-context or have paraphrased a source, and that might provide inexact depictions of an original message. Statements and the perception of semi-autonomous powered-wheelchairs within the news ought consequently to be considered carefully. When the news stories were studied together then some interesting potential trends emerged. Nineteen articles, six quotes and paraphrases and sixteen reports of interviews were considered. Smart was often used synonymously with powered-wheelchair or as an all-encompassing expression incorporating semi-autonomous powered-wheelchairs. The term intelligent powered-wheelchair was used in seven. Nine articles use the words automation or automated in the discussion of semi-autonomous powered-wheelchairs. In none of these articles was there a clear distinction between the terms. In some articles, the words seem to be used synonymously.

Using automation and autonomy synonymously did not appear to be becoming less common over time. Separation between terminologies was not clear in six out of nine 2020 articles. Of documents printed before 2020, only five out of the thirteen had unclear separation. In only three news stories was it well-defined that autonomy didn.t mean un-manned. A quote in one story joined autonomous to un-manned, so that the story showed both "unclear" and "clear" separation. However, four stories specified that autonomous vehicles weren't necessarily un-manned, and autonomy might be used for wheelchairs. Statements implying that autonomous is un-manned were somewhere in the text in all the stories.,

Some documents make a distinction between autonomous and semi-autonomous, while others assume that remote-control is a type of autonomy. Safety of semi-autonomous powered-wheelchairs for both the wheelchair and the driver is often mentioned, appearing in most documents. In most cases, it was specified that the improvement in safety was a result

of reduced human error. That claim is contested in some documents. Reducing costs was cited three times, while optimizing efficiency was highlighted in technical articles (although one did challenge that). Reduced carer costs also had two mentions. Regarding challenges in the development of semi-autonomous powered-wheelchairs, the fact that the business case is not yet clearly proven is occasionally mentioned, the issue of road and traffic legislation not accommodating semi-autonomous powered-wheelchairs is mentioned once. Other challenges mentioned were user skill degradation, data security and perception of the general public.

5 DISCUSSION

There is general agreement on some aspects. Semi-autonomous powered-wheelchairs need more sensors and automation. Some documents said autonomous meant un-manned, while others said it certainly did not (Eriksen, 2019). But many documents either said autonomous may be manned in one place but then used un-manned and autonomous synonymously or they were sometimes vague in making a distinction. That ambiguity appears to be common.

There is a trend in the scientific literature for recent papers to be clearer in separating autonomous and semi-autonomous and un-manned. There may be an increasing awareness of the need to define autonomy because of the ambiguity. That is not true of news stories though where they tend appear to be becoming less and less clear about the separation between autonomous and automation and semi-autonomous. Definitions of autonomy have come to mean something closer to automation so that the expressions are used synonymously. Awareness might also be increasing.

A lot of ideas about autonomy are related to un-manned operation but that is not relevant in assistive technology. Removing a carer and providing more autonomy for the users is only possible if a wheelchair is semi-autonomous. If a carer is still required then costs are similar even if they are doing less, they may also be subjected to more complicated and stressful working conditions.

As human drivers are still within the control loop, it is difficult to assess the benefits of increased safety for powered-wheelchairs and drivers due to reductions in human error. Increased safety is often mentioned as a benefit of using a semi-autonomous powered-wheelchair, but it can be contested. Other benefits can be derived from making control systems simpler to use, possibly with more sensors and greater

redundancy. There might be better reliability and increased efficiency but that is not always clear.

6 CONCLUSIONS

The concept of a semi-autonomous powered-wheelchair is understood but there isn't any agreement about a definition, for example of autonomous, semi-autonomous and un-manned (Eriksen, 2019). There is an increasing awareness within scientific material of the need to separate terms, but that has not filtered out into newspaper stories.

The changing perceptions of what autonomous, automatic and semi-autonomous mean (and whether any means un-manned) hasn't altered the expectations about what autonomy might bring. Whether autonomous systems are un-manned or not has a massive influence on their expected benefits. Most benefits of semi-autonomous powered-wheelchairs are related to assisting the wheelchair user on board their wheelchair. What a semi-autonomous powered-wheelchair is if it is un-manned is not clear. Many researchers have defined what a semi-autonomous powered-wheelchair is, and academic and technical papers have defined autonomy (and sometimes different levels of increasing autonomy). That is important, but definitions haven't been understood by the general public.

REFERENCES

Sanders, D., Tewkesbury, G., Graham-Jones, J., 2011. *Simple rules to modify pre-planned paths and improve gross robot motions associated with pick & place assembly tasks*, Assembly Autom, 31 1 pp 69-78.

Sanders, D., Graham-Jones ,J., Gegov, A., 2010. *Improving ability of tele-operators to complete progressively more difficult mobile robot paths using simple expert systems and ultrasonic sensors*, Industrial Robot: An International Journal 37 5 pp 431-440.

Sanders, D., Lambert, G., Graham-Jones, J., Tewkesbury, G., Onuh, S., Ndzi, D., Ross, C., 2010. *A robotic welding system using image processing techniques and a CAD model to provide information to a multi-intelligent decision module*, Assembly Autom 30 4 pp 323-332.

Haddad, M., Sanders, D., Langner, M., Bausch, N., Thabet, M., Gegov, A., Tewkesbury, G., Ikwan, F., 2020d. Intelligent control of the steering for a powered wheelchair using a microcomputer. In *SAI Intelligent Systems Conference*. Springer.

Sanders, D., Tewkesbury, G., Stott, I., Robinson, D., 2011. *Simple expert systems to improve an ultrasonic sensor-system for a tele-operated mobile-robot*, Sensor Review 31 3 pp 246-260.

Haddad, M., Sanders, D., 2019. *Selecting a best compromise direction for a powered wheelchair using PROMETHEE*, IEEE Trans. Neur. Sys. Rehab. 27 2 pp 228-235.

Eriksen, S., 2019. *Autonomous Ships – Changing Perceptions and Expectations. 18th International Conference on Computer and IT Applications in the Maritime Industries*, Technische Universität (Hamburg) pp 33-39.

Hornby, A., Ashby, M., Wehmeier, S., 2005. Oxford advanced learner's dictionary of current English, Oxford, Oxford University Press.

Haddad, M., Sanders, D., Ikwan, F., Thabet, M., Langner, M., Gegov, A., 2020c. Intelligent HMI and control for steering a powered wheelchair using a Raspberry Pi microcomputer. In *2020 IEEE 10th International Conference on Intelligent Systems-IS*. IEEE.

Rødseth, Ø., Burmeister, H. 2012. Developments toward the un-manned ship. In *Int. Symp. Information on ships*. Un-manned-ship.

@Listverse. *10 Words That Originally Meant Something Really Different* Feb. 12, 2016. Accessed on: Feb. 8, 2021. [Online]. Listverse. Available: https://listverse.com/2016/02/12/10-words-that-originally-meant-something-really-different/

Cambridge Dictionary. 2019. *Cambridge Business English Dictionary* Accessed on Feb. 8, 2021. [Online]. Cambridge University Press: https://dictionary.cambridge.org/dictionary/english/automation