# Autonomy vs. Safety in Shared Control Crowd Navigation

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***Abstract*— Shared control is a paradigm with great potential for increasing the autonomy of people who would otherwise struggle to use an electric powered wheelchair: by automatically handling tasks that the driver cannot, the wheelchair can ensure their safety and that of others when in shared spaces. However, imposing a uniform definition of safety on to wheelchair users runs the risk of actually diminishing their autonomy by removing their ability to assess risk and make decisions themselves. This issue is magnified in crowds, where one is responsible not only for one's own safety, but also that of the other pedestrians. In this abstract we raise a number of related ethical issues that we have identified that are applicable to shared control in crowded spaces, as well as propose a framework for thinking about these issues.**

## I. Introduction

Moving through a crowd is a complex interaction where one must constantly track the movement of other pedestrians, as well as predict their behaviour. "Will they let me pass, or should I move aside?" Most pedestrians have a choice of how to negotiate these interactions, engaging in prosocial behaviours like making way for others, or selfish ones like pushing and blocking space. The latter set of actions reduce the ability of others to move and can put them at risk of injury (such as when adjacent to a busy road). A shared control wheelchair exists to allow an impaired driver to move in public spaces without risking injury to themselves or others, but also to execute their desired movements [1]. What happens when these two directives are in conflict? A rational pedestrian may engage in risky or antagonistic behaviour, if they believe their goal is important enough (to reach a crucial appointment, for example). Removing these options from a wheelchair user could be viewed as counter to the goals of assistive technology, robbing them of choice others take for granted and implicitly devaluing their judgement. If we, as designers, give the user an ability to take risks that they would not otherwise possess, as discussed in [2], does the responsibility fall to us when that ability causes harm? We present a perspective on how user autonomy and safety can be balanced in shared control and how the technical features of a controller can affect this weighting.

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## II. Weighting Autonomy vs. Safety

Physical safety requirements for wheelchairs are defined by the ISO7176 standards, including static stability, maximum speed, braking effectiveness, and obstacle climbing ability. For the shared control scenario, algorithmic safety mechanisms must also be implemented, in addition to adhering to the physical dimensions defined in ISO7176 [3] for appropriate sensor placement.

The unspoken assumption behind these powered wheelchair standards is the same as for any vehicle: a trained driver can make appropriate safety decisions, and their control of the vehicle is such that it will always act on their intentions. Shared control lacks these assumptions: the driver may not have the sensory information (e.g. due to visual impairment) or cognitive competency to make appropriate decisions, and they may be unable to communicate those decisions using a standard input device.

A reasonable goal would then be that the shared controller should attempt to enact the end-user's intentions within the scope of their ability to make informed decisions and take the safest course of action otherwise. However, driving competencies vary greatly, and may not be evenly distributed even among patients with the same conditions. The obvious solution to this is to make the shared control parameters customisable, just like the rest of a wheelchair (seat, leg rests, acceleration profiles etc.). However, there is a risk these options will not be used if they are too complex.

A controller that privileges safety over user autonomy is easier to design because it can be largely user agnostic. A patient who does not meet the basic competency test to be allocated a powered wheelchair benefits most, because any possibility to use the wheelchair will improve their autonomy. Moreover, in principle safety-preserving control benefits any user, if only slightly.

The counter argument is that user autonomy should be given a stronger emphasis simply because it is psychologically and developmentally beneficial. Greater self-determination (encompassing user autonomy) has been associated with better outcomes for children with learning disabilities [4], a core target group for shared control wheelchairs. Finally, it is important to distinguish behaviours that are unsafe

| | Level 0 | Level 1 | Level 2 | Level 3 | Level 4 | Level 5 | Level 6 |
|---|---|---|---|---|---|---|---|
| Required user engagement | The user is constantly engaged. | The user is constantly engaged. | The user is nearly always engaged. | The user is nearly always engaged. | The user is regularly engaged. | The user is intermittently engaged. | The user is not engaged |
| User input modification | None.<br><br>The user drives the wheelchair directly using the input device. | Minimal modification.<br><br>The wheelchair closely follows user input, and will not act unless the input device is in use. | Moderate modification.<br><br>The wheelchair can act for short periods when the input device is not in use and ignore inputs that seem to be erroneous. | Significant modification.<br><br>The wheelchair modifies their input to avoid obstacles and/or optimise the trajectory with respect to velocity or other metrics. | Full replacement.<br><br>The wheelchair generates trajectories that the user can select between using the input device. | Full replacement.<br><br>The wheelchair generates a trajectory based on inferred user intent from the input device. | Total.<br><br>There is no input device and user intent is ignored. |
| Examples | Standard powered wheelchair | Tremor reduction [5] | Discrete 'latched' user commands [6] | Virtual force field methods [7] | User-directed automated navigation [8] | Probabilistic Dynamic Window Approach [1] | Self-driving wheelchair 'taxi' |

Fig. 1. Suggested framework for classifying the level of assistance in a shared control wheelchair: levels 1 through 5 represent shared control, while levels 0 and 6 are full user control and a full autonomous wheelchair, respectively.

from those that are merely undesirable. The end-user may wish to control or minimise the visible effects of their impairment for various reasons [9], [10], not least the potential reactions of other pedestrians, but it is important not to impose this assumption without consultation with appropriate stakeholders.

## III. Classifying Levels of Intervention

In order to approach this problem in a principled way, we draw inspiration from the autonomous vehicle community to propose a framework where shared control systems are classified by the degree to which the wheelchair's motion resembles the end-user's input (Fig 1). Safety-based assisted control methods would occupy a level between 3 and 5 within this framework. As the level of modification increases it is expected that the user's perception of autonomy will decrease. For this reason, we recommend that researchers are careful not to design systems that 'over-assist' and, if possible, give appropriate stakeholders (prescribers, carers and/or end-users, depending on competency) the ability to modify the level of assistance, especially when we consider that the correct level of shared control for a user may change over time as they become more experienced driving a powered wheelchair, or their condition worsens. This further requires an interface that is accessible to a layperson, providing options that will have clear outcomes for the user.

## IV. Conclusions

Shared control raises unique ethical issues that are not merely a 'mid-point' between those of user-controlled vehicles and self-driving robots; namely how to balance safety and personal autonomy. We recommend a principle where the end-user's input should be modified by the minimum possible degree to ensure safety, giving the user as much autonomy as possible. This leads to the related principle that the level of assistance should be modifiable and framed in terms that laypeople (prescribers, carers and/or users) will understand.

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