Wheelchair navigation and unilateral neglect: Can the use of technology improve performance?

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Following stroke, the deficit of unilateral neglect (also referred to as *spatial neglect*, *hemi-inattention* and *the neglect syndrome,* amongst other terms) is associated with poor outcome with affected patients relatively unlikely to relearn to walk (Buxbaum et al., 2004). The outlook for regaining independent mobility is made still worse by the general inability of patients with unilateral neglect to effectively use a power chair, a device that is known to have a profoundly positive impact on the quality of life of disabled individuals (Davies et al., 2003; Woods & Watson, 2003). Indeed, the presence of unilateral neglect normally excludes individuals from even accessing assessment for a power chair (Frank et al., 2000).

Defined as an inability to report, respond or orient to stimuli presented on the side of space opposite a brain lesion (Heilman et al., 1985), patients with unilateral neglect are typically unaware (or less aware) of events taking place on one side (the contralesional side) of space. Studies have confirmed the clinical observation that affected patients tend to bump into obstacles on this side when navigating around their environment (Webster et al., 1989; Punt et al., 2008).

It is known that some patients will improve their ability to use a power chair with practice early after stroke (Dawson & Thornton, 2003; Mountain et al., 2010). Furthermore, interventions have been developed to improve the skills of affected patients in the more chronic stages (Punt et al., 2011; Jacquin-Court et al., 2008). However, it remains the case that the vast majority of affected patients will not access powered mobility and those who do will normally be found to be unsafe navigating around their environment.

The development of new technology may offer the prospect of improving access to powered mobility for patients with unilateral neglect. Around the world, numerous groups have developed 'smart' technology for power chairs (see Simpson, 2005 for a review) but an effective and affordable solution for patients with unilateral neglect remains elusive.

We recently tested the navigational skills of nine patients with unilateral neglect on an obstacle course in a rehabilitation centre. We also assessed the impact of a collision-avoidance system (known as the *Anti-Bump System* or ABS) on these same patients. The ABS was developed a number of years ago by the Special Controls Service - part of the Posture and Mobility Service at the West Midlands Rehabilitation Centre - and supplied with some success to a child with cerebral palsy who displayed general inattention to his surroundings whilst driving his chair. The system allows normal use of a power chair via joystick control. However, a series of infra-red sensors mounted on the chair (see Fig.1) can be triggered when an obstacle is in close proximity and, through communication with the control system of the chair, momentarily turns the chair away from the obstacle, the chair then returning to normal joystick control by the user. As such, the system appeared to have particular utility to improve performance for patients with unilateral neglect.

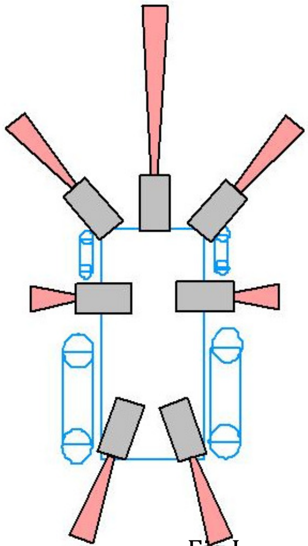

Fig I

Our tests revealed some promising results. Patient performance on the obstacle course was measured by counting the number and side of errors. In addition, and in common with an earlier study investigating wheelchair navigation (Webster et al., 1989), we separated errors into 'direct hits' (i.e. head-on collisions where the front of the chair collided with an obstacle) and 'side swipes' (i.e. where the front of the chair successfully avoided an obstacle but was still disturbed by a more posterior part of the chair).

Across the nine patients tested, there were fewer errors when the ABS was active (0.36 per trial) than when it was inactive (0.42 per trial). For errors on the 'affected' side, direct hits were more noticeably reduced when the ABS was active (0.16 per trial) compared with when it was inactive (0.65 per trial). However, side swipes on the affected side **increased** at the same time (inactive = 0.74 per trial; active = 0.97 per trial). None of these differences were statistically reliable. The data are shown in Fig 2.

Our findings were perhaps less clear due to variation in navigation ability across the sample. A number of patients had very mild problems and performed well under control conditions, leaving little room for improvement under ABS conditions. For the two patients who had more marked difficulties, the ABS had a more dramatic effect, reducing direct hits more markedly than the group data suggest (1.2 to 0.4 and 1.3 to 0.3 per trial for these cases).

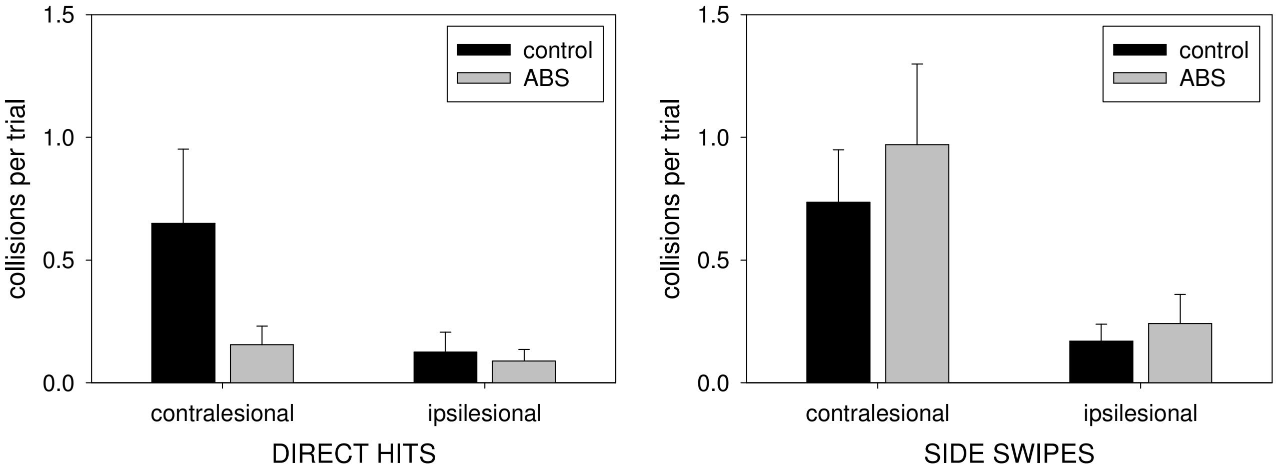

Fig 2

However, a reduction in direct hits for these patients was accompanied by an increase in side swipes (0.8 to 1.0 and 0.9 to 1.6). In some cases, side swipes were due to the chair avoiding a collision (due to ABS activation) on one side, only to generate a side swipe on the other. While, on balance, one would conclude that performance was improved by the ABS, these problems highlight the current weaknesses of the system, and inform challenges for the future with regards to further development.

It is difficult to know how these results might translate into real world improvements for patients using the ABS within their normal environment. We deliberately created a challenging course with some very narrow gaps and tight turns. In all probability, many environments would not provide the same degree of challenge with regards to these aspects. However, a very careful assessment of the environment within which the ABS is intended to operate would be essential to minimise risk.

For patients with unilateral neglect, encouraging them to have primary control of the power chair seems appropriate. Patients typically have some degree of hemiparesis but, due to the right brain damage bias typical in the neglect population, more often than not patients have relatively good use of their dominant limb and can easily manage a normal joystick control. However, while they can generally plan a broadly appropriate route and steer in the overall intended direction, their tendency to collide with obstacles (particularly on their neglected side) means that some form of collision-avoidance would be required. To some extent, the ABS can provide this secondary control and together one might consider the chair to be operated under 'shared' control, an approach that is now being recognised by other groups as optimal in the development of technology to provide greater access to powered mobility (Carlson & Demiris, 2008).

Participants were generally unaware in terms of their knowledge of when the ABS was active or not, and this is reassuring with regards to its potential utility. The aim of the ABS is not to become too imposing on the user's experience as an active driver. The responses of participants appear to suggest that deviations in their trajectory when the ABS was activated are not sufficient to either be noticed or to be a distraction. In terms of usability, this is optimal, but one may want to adapt the ABS to prompt patients when the system is activated. For example, another potential function of the ABS is in rehabilitation as a training wheelchair, where providing a sensory signal or cue (e.g. an auditory tone) would build on evidence from studies that have shown spatial cues to shift patients' attention to their neglected side (Riddoch & Humphreys, 1983). Having a patient train to use a powered chair fitted with the ABS within a controlled environment, and with these modifications, could be an effective training strategy, and would negate the requirement for a vigilant therapist to supervise training sessions as would currently be the case.

For a collision-avoidance system to demonstrate optimal utility, one might expect it to allow the user to avoid collisions altogether. In our tests, this was clearly not the case, and user environments may well be more challenging (in numerous ways) in comparison to our obstacle course. Limitations of the ABS include its inability to reliably detect obstacles, a problem which includes difficulties in both consistently detecting obstacles when they are a given distance from the sensor, and also 'coverage' around the chair. The infra-red sensors employed by the ABS may have an inherent weakness in this regard and may be more problematic in complex environments. While increasing the number of sensors may eliminate the occasional blind spot we encountered, the difficulty in consistent response is likely to remain. Developing the ABS using a higher specification of sensor (e.g. sonar) may improve this issue, though these are not without their difficulties (Dutta & Fernie, 2005). Sensors with a higher specification would also increase costs.

Even with development, the ABS would require the user to operate it within a relatively controlled environment. However, one could imagine an effective collision-avoidance system enabling users to benefit from powered mobility in environments such as care homes and their own homes where one could impose some constraints on potential hazards. Safety issues for the user and other residents would be of primary concern (Mortenson et al., 2005) and collision-avoidance capability is likely to be one contribution to a broader approach to enablement that would be required for powered mobility to become more common in these environments (Dutta et al., 2011).

In summary, our study has demonstrated the feasibility and potential benefits of the ABS in a relatively well-defined group of patients who are currently denied access to powered mobility. However, technological limitations require further developmental work and it is likely that technology is one of numerous components that need addressing if more patients are to gain access to powered mobility. Importantly, the need for engineers, clinicians and users to work together in this endeavour is essential.

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