Novice vs experienced wheelchair users: perceived difficulty of task performance with and without a push-rim-activated power assisted wheelchair (PAPAW)

Roxana Ramirez Herrera[1,2], Shawn Joshi[3,4], Dafne Zuleima Morgado Ramirez[1,2], Tom Carlson[3], Helen Dawes[4],Catherine Holloway[1,2]

[1]*University College London Interaction Centre; [2]Global Disability Innovation Hub, [3]School of Biomedical Engineering,Science & Health Systems,Drexel University;[4] Centre for Movement,Occupational and Rehabilitation Sciences,Oxford Brookes University; [5]Aspire Create,University College London*

INTRODUCTION

Manual wheelchairs are the most common assistive technology for locomotion for people with motor impairments that prevent them from walking[1]. The ability to self-propel is vital and is linked to a higher quality of life. It allows wheelchair users to remain active, and therefore, decreases the risk of diseases associated with sedentarism as well as allowing for the positive benefits associated with performing activities of daily living [2].

As regular manual wheelchair (RMW) self-propulsion is not mechanically efficient [2], long-term wheelchair use can lead to upper limb strain[3], injury and even loss of function [4]. Push-rim activated power assisted wheelchairs (PAPAWs) have been shown to reduce strain on the upper limbs and cardiovascular system and reduce metabolic demand when compared to regular hand-rim propulsion [6]. The use of push-rim activated power assisted wheelchairs (PAPAWs) can help provide the extra power needed for self-propulsion when people do not have the power to self-propel, or lose this function due to injury, while keeping the benefit of activity [5]. Studies have also shown that PAPAWs make it easier to perform tasks that require high torque, such as ascending or descending ramps and managing uneven surfaces, but precision tasks, which require more maneuverability, will be more effective when performed with regular hand-rim propulsion[6].

Studies on power assistance effects and learning have so far looked separately at novice users or abled-bodied participants [e.g. 7,8] and wheelchair users[e.g. 9,10].The use of able-bodied participants as proxies for real novice users has been accepted in literature when studying early acquisition of wheelchair skills proficiency [11], given the difficulties of recruiting new manual wheelchair users in actual need of the chair. However, for the case of experienced wheelchair users that will eventually need to switch to PAPAWs, interference of habitual patterns could have an influence on ability to perform some wheelchair tasks [7]. As wheelchair skill performance depends on wheelchair experience [12], the influence of such patterns in task difficulty needs to be taken into account when investigating PAPAW propulsion in initial stages of motor learning. Assessing the difficulty of a range of tasks in both novice and experienced users could be of benefit, as it may be used to guide wheelchair training. Knowledge of task difficulty could aid the decision to use PAPAWs or help therapists to design teaching strategies based on individual wheelchair experience (whether they are transitioning to PAPAW or using PAPAW as their first wheelchair).

In this study we document the ranking of perceived tasks difficulty by novice and experienced wheelchair users over a range of representative wheelchair tasks across two wheelchair modes: RMW and PAPAW. We hypothesize that 1) there is a significant difference in perceived difficulty for each of five key tasks between RMW and PAPAWs, within each population group: novice and experienced wheelchair users being presented with PAPAW for the first time, and 2) that there is a significant difference in perceived difficulty across wheelchair tasks, when using PAPAWs, between the two population groups.

METHODS

Participants

Thirty-three participants were recruited as part of a larger study on cognitive load and wheelchair usage. Nineteen non-disabled individuals (7 males, 12 females) posed as novice users with mean age 30.89±9.07 years, mean weight 69.54±14.18 kg and mean height 1.72 ± 0.11 m. Experienced wheelchair users (5.92± 4.84 mean years of experience) were 8 males and 6 females, with mean age 28.20 ± 8.64 years, mean weight 80.98±15.93 kg, and mean height = 1.70 ±10.24 m. Among the experienced users, five participants had Ehler Danlos Syndrome, five participants had spinal cord injury (T4,T5-T10,C6,C7/8,L4/5), two had Spina bifida, one had transverse myelitis(T9), and one was a lower limb amputee with cerebral palsy. All participants were able to self-propel.

Procedure

Ethics approval was obtained from University College London Interaction Centre Ethics Committee. The study took place at an experimental setup at the Indoors Sports Hall of Oxford Brookes University in Oxford, UK. During each experimental session and after providing consent, participants were requested to perform 5 different tasks that encompassed different wheelchair skills required to negotiate typical pushing scenarios, defined in Table 1. Description of five tasks performed by participantsTable 1.

Table 1. Description of five tasks performed by participants

Task	Code	Description
Task 1	**Level surface**	**Propulsion over smooth, level surface**. Consisted of propelling the wheelchair on a basketball court along the perimeter of a rectangular area of 13 m x 14 m (total distance travelled of 54 m).
Task 2	**Uneven terrain**	**Propulsion over uneven terrain**. Participants propelled the wheelchair over a path, 7m long, covered with parallel foam pool noodles (width = 0.80 m, diam = 0.05 m, separated by 0.03 m) which mimicked a high friction surface.
Task 3	**Cross slope**	**Managing cross slopes.** The tasks consisted of climbing two side slopes, each with a travel distance of 2.4 m, gradient of 10° and 0.20 m high, 0.70 m apart from each other. One of the slopes was ascending left and the other ascending right. Participants were requested to climb the first slope, exit and then climb the second slope and exit.
Task 4	**Ramp**	**Ascending and descending an incline.** Participants were requested to ascend a 3m long ramp with a 5° gradient to a step of 0.26 m high, then roll over a level surface of 0.50 m at this height and descend a second 3m ramp with same gradient. Dimensions of ramp were chosen following guidelines for maximum ramp dimensions from the American Disability Association (ADA) standards for Accessible design 2010 [13].
Task 5	**Cones**	**Maneuvering cones.** Participants were asked to weave between 7 cones without hitting them, set 0.92 m apart from each other. The distance between cones corresponds to the minimum acceptable door width (ADA standards [13]).

Participants were requested to perform 8 repetitions of each task, four repetitions with the PAPAW and four repetitions with RMW. The wheelchair propulsion mode (PAPAW or RMW) of each repetition was randomly allocated. All participants used the same wheelchair: a standard manual wheelchair Quickie Life R fitted with M24 Alber Twion power assist wheels, which were switched on or off depending on which of the two modes the subject was supposed to be testing. The wheels were used in ECO mode setting allowing maximum propulsion speed of 10 km/h to prevent accidents. To ensure safety for participants and increase confidence in novice users, the wheelchair was fitted with rear anti-tipping devices. However, these were removed upon request for 4 of the more experienced wheelchair users, as they felt they interfered with their technique.

Each experimental session took around 40 min to be completed, during which participants were given resting periods in between repetitions of 30 to 50 seconds. Each session was video recorded with a GoPro camera, mounted on the walking track above the experiment court, allowing for the full set up to be captured. Before each session began, participants were given a 10-20 minute introduction on how to perform the 5 wheelchair tasks to be completed, with advice taken from the Wheelchair Skills Program Manual v4.3 [14]. During this introduction, participants were given the opportunity to practice the skills up to the point where they felt safe on performing them on their own. At the end of each session, participants were asked to rank, using a score from 1 to 5, the difficulty of the 5 tasks performed with and without power assist, with 1 corresponding to the easiest task and 5 to the most difficult one.

Analysis

The average weighted score of perceived difficulty for each task in both wheelchair propulsion modes (RMW or PAPAW) for both population groups (novice and experienced users) was calculated and used to rank the tasks from least difficult to most difficult (see **Table 2**). A boxplot of Tasks vs Difficulty scores for both populations can be seen in Figure 1. Due to the small sample size and non-normality of ordinal data, a Wilcoxon rank-sum test was performed to evaluate the first hypothesis, and a Mann- Whitney U test using an exact sampling distribution of U for the second. Statistical tests were performed using IBM SPSS Statistics package V25. Significance level for all statistical tests was considered at $p<0.05$.

Table 2. Ranking of task difficulty

Novice users	Wheelchair users
Without power assist 1. Level surface (1.16) 2. Uneven terrain / Cones (2.74) 3. Ramp (3.84) 4. Cross slope (4.53)	**Without power assist** 1. Level surface (1.00) 2. Ramp (3.00) 3. Cones (3.21) 4. Uneven terrain (3.57) 5. Cross slope (4.21)
With power assist 1. Level surface (1.42) 2. Uneven terrain (2.05) 3. Ramp (3.32) 4. Cones (3.89) 5. Cross slope (4.32)	**With power assist** 1. Level surface (1.29) 2. Ramp (2.29) 3. Uneven terrain (2.86) 4. Cones (3.86) 5. Cross slope (4.64)

RESULTS

For our first hypothesis, in the case of experienced wheelchair users, there was a statistically significant median decrease (1.138) in perceived difficulty in task 4 (ascending/descending incline), $z = -2.058$, $p =0.040$; and a significant median increase in difficulty score (0.928) for task 5 (cones), when using PAPAW, $z = -2.179$, $p = 0.029$. As for the case of novice users, there was a statistically significant median decrease (1.00) in difficulty score in task 2 (uneven surface), $z=-2.440$, $p=0.015$, and a statistically significant median increase (1.00) in difficulty score in task 5 (cones), when using power assistance, $z = 3.002$, $p = 0.003$.

In the case of our second hypothesis, distributions of the perception of difficulty for both population groups were not similar, as assessed by visual inspection. In the case of power-assisted mode, for task 2 (uneven surface), difficulty score for novice users was significantly lower (mean rank = 13.39) than wheelchair-users (mean rank = 21.89), U= 64.500, z = -2.643, p = 0.011. In the case of task 4 (ascend/descend incline), difficulty score was significantly higher for novice users (mean rank = 20.74) than wheelchair-users (mean rank = 11.93), U = 62, z=-

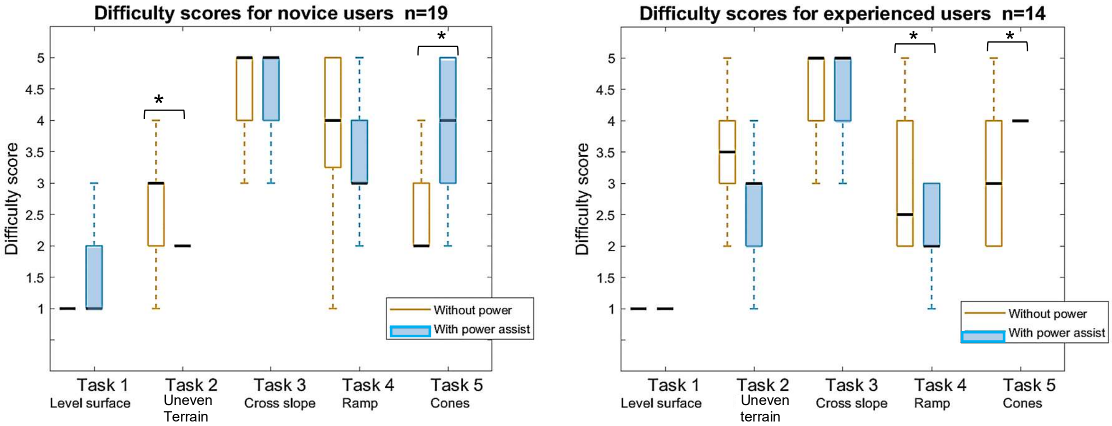

Figure 1. Difficulty scores, both populations, with PAPAW and without power assist (RMW), *p<0.05

2.667, p = 0.009. The rest of the tasks did not show a statistically significant difference. Without power assist, the only task that showed significant statistical difference between groups was managing an uneven surface (task 2), with novice users (mean rank = 13.71) scoring it easier than experienced wheelchair users (mean rank =21.46), U = 70.5, z = -2.443, p = 0.021.

DISCUSSION

The current study is one of the first to compare perceived difficulty scores of both novice and experienced wheelchair users when being introduced to the use of PAPAWs. Results suggest that there is a difference in perceived difficulty between the two groups when performing certain tasks.

Interesting results are seen on scores for managing uneven terrain. When comparing the scores of RMW with PAPAW, novice users show a significant decrease in perceived difficulty for this task. This is congruent to what literature has repeatedly reported: PAPAWs are particularly helpful over irregular surfaces [6,8–10]. In the case of experienced users, even though from visual examination of boxplots there is a decrease in difficulty for this task, it was not statistically significant. Moreover, when comparing performance between groups (new users vs experienced users) with PAPAW, data suggests that experienced users rank managing uneven terrain as more difficult than novice users do. One of the possible explanations for this difference is PAPAW interfering with wheelchair users' technique or with a pre-existent mental model of the wheelchair dynamics. For instance, wheelies are an advanced technique that is sometimes used to manage rough terrains, and becomes more difficult and dangerous when performed with PAPAW [15]. Although not a prevalent skill between regular wheelchair users [15,16], video recordings show that some users in this group were trying to approach the task with such technique (e.g. those being amateur athletes, n=3). However, as doing a wheelie with PAPAW reduced control, then they had to switch to another technique to which they were probably not used to.

Important differences are also noted when participants were performing the task involving ascending and descending an incline. For experienced users, perceived difficulty decreased when comparing MW with PAPAW, and it was significantly easier for them when compared to novice users in power assist mode. Again, this is consistent with PAPAWs being found to help with tasks that require high wheel torque [6,8–10]. Difficulty of incline task decreased for novice users, although not statistically significantly. It could be the case that for some novice users, high torque is not sufficient to compensate for an inadequate propulsion style. A lack of confidence in wheelchair skill capacity could also have an impact on their perception of difficulty given that this task in particular, due to the high inclination angle, could be perceived as more unsafe than the rest.

Both novice and experienced wheelchair users showed a statistically significant increase in perceived difficulty when using PAPAW, when maneuvering cones (task 5). This is consistent with previous studies [6,8–10], given that negotiating obstacles within limited spacing requires a high level of precision. We can also observe that for this particular task, novice users presented a higher increase in median difficulty than experienced users when in power assist mode. In this particular situation, experienced wheelchair users could have been benefited in a smaller degree from positive skill transfer from previous expertise, but this needs to be further examined.

As we recognize the limitations that come from assessing task difficulty by rank order among a small sample size, our results are merely indicative for an experienced wheelchair population. Other factors could have influenced the rank order, such as the unfamiliarity with a new wheelchair, experience or fitness level. Future work will investigate what is suggested in this study by using objective metrics of exertion and performance (e.g. physiological data, movement analysis) for assessing wheelchair skill difficulty differences and using a larger sample group. Future work will also look at the influence of demographic factors, (e.g. gender, medical condition) and evaluate a more comprehensive group of tasks. An additional path worth exploring involves examining wheelchair tasks which could have been affected by skill transfer from RMW to PAPAW use and identifying the characteristics that determine whether they will ease or interfere with power assist usage assimilation. We encourage the research community to further investigate training methods which could help RMW users better transition to PAPAW use and to PAPAWs manufacturers to work with RMW users to design more maneuverable PAPAW devices. Given that PAPAWs can be acquired outside of the health care system, it is also interesting to consider how best educate users who might acquire devices privately.

CONCLUSIONS

Results suggest that there is a difference in perceived difficulty between the two groups (novice and experienced wheelchair users) when using PAPAWs, with experienced users ranking ramp as easier and uneven terrain ranked as more difficult, when compared to novice users. Within subject comparison of perceived difficulty between RMW and PAWAs in both groups is congruent with literature, with high torque tasks ranked easier and high precision tasks ranked more difficult with PAPAWs. Detailed analysis is needed of how experienced and novice wheelchair users can best be helped gain the skills required to use a power assist system.

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