Interface Modality Informing Assistive Autonomy

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I. INTRODUCTION

When a person with a particular impairment is fitted for an assistive device such as a powered wheelchair, the seating clinician will take the unique physical abilities and constraints of the individual into account, especially when choosing the control interface they will use. The chosen interface can affect how a person operates their device and what operational challenges they may face. Often, the limitations of the specific interface hinders the performance of the user.

There is a distinct difference in how people physically provide input commands through different interfaces (e.g. motion of the hand via a joystick, or through regulated breathing via a sip/puff device). Furthermore, the same interface may be mapped to the control output in different ways. For example, the input of a sip/puff device may be mapped proportionally or non-proportionally to the control command. We see differences in usage characteristics across interfaces which impact the overall human-robot team performance [1].

Autonomy, and more specifically shared-autonomy, can offset interface limitations to improve performance. In order to be effective, the shared-autonomy assistance should be aware of the usage characteristics of the interface and adjust to varying performance characteristics of the person. Unfortunately, little work characterizes common interfaces. Most similarly, some work focuses on novel interfaces [2], [3] or features not suitable for assistive autonomy [4] [5].

We provide the results of a pilot study that aims to determine if the form of input (hand motion, head motion, and breath) is the main reason for differences in interface usage, or if the differences are based on the features of the interface such as proportionality and input dimensions. This knowledge will aid in designing interface-aware shared-autonomy paradigms.

II. EXPERIMENTAL METHODS

The study was conducted using three interfaces and two open-source computer game tasks we developed for evaluating interface operation [1]. The three interfaces for this study were particularly selected, since they are the most common types of interfaces employed by SCI users of powered wheelchairs [5]. The selection used in this study were (1) a 533 Compact joystick (ASL, TX, USA), (2) 105 electronic headarray system (ASL, TX, USA), and (3) sip/puff switch (Origin Instruments, TX, USA), which are normally two dimensional proportional, two dimensional discrete, and one dimensional discrete controllers, respectively. In order to see whether the form of control input has an effect on the differences in performance measures, we also mapped the headarray and joystick interfaces similarly to the sip/puff device which is 1D, discrete, non-proportional, and requires mode switching between rotational and translational motions with a chin button (*joystick mapped* and *headarray mapped*). The only variable remaining is the method of input (i.e. hand, head, and breath).

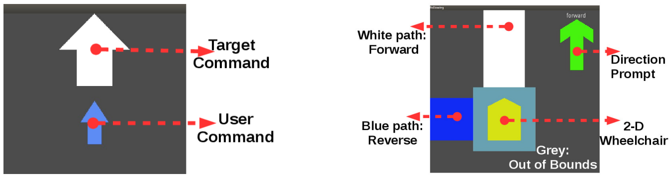

Fig. 1: Command (*left*) and trajectory (*right*) following tasks.

1) Tasks: The experiment consisted of a command following and trajectory following task. The tasks were designed in a simulated environment so that uncertainties from real world dynamics did not corrupt the performance measures.

Command Following The command following task was designed to assess a subject's ability to respond to a visual command stimulus in terms of accuracy of response, response time, and how steadily they issued a specific command (Fig. 1, right). In this task, a white arrow—the command prompt $\hat{\mathbf{u}}$—appeared on the screen pointing in different directions in a randomly balanced sequence. The directions included the four cardinal angles. The subject was instructed to issue a command for the same direction as soon as they saw the command prompt and to continue issuing the command uninterrupted for the duration of the prompt (T). The blue arrow was the feedback of the command the user was currently issuing.

Trajectory Following This task assessed the ability to follow a trajectory with a single known goal—without interference from wheelchair dynamics and external sources of noise—and aimed to illuminate how a person's intended goal may differ from the signal they output through the interface (Fig. 1, left). The task involved controlling the motion of a 2-D simulated wheelchair (the yellow pentagon shape) along a predefined path. The trajectory began with a square path, followed by a curved path. Only the path in the immediate vicinity of the wheelchair was visible at any given moment. The square and

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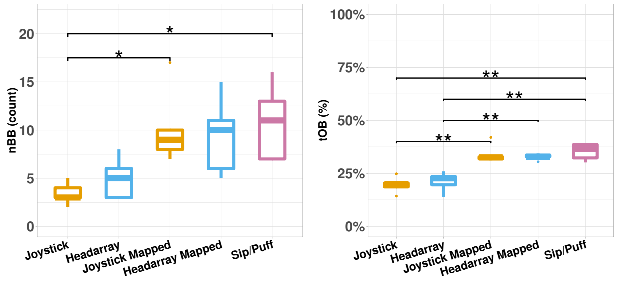
[1] Source code: https://github.com/argallab/interface_assessments



(a) (b)

Fig. 2: Trajectory following. (a) Number of times participants broke the path barrier (nBB). (b) Percent of task time when participants were not fully within the marked path (tOB).

curved paths were designed such that they contained the basic commands covered by all three interfaces. The square path consisted of two forward, two backward, two 90° left turn and two 90° right turn trajectories. The curved path consisted of two long arcs and two small arcs.

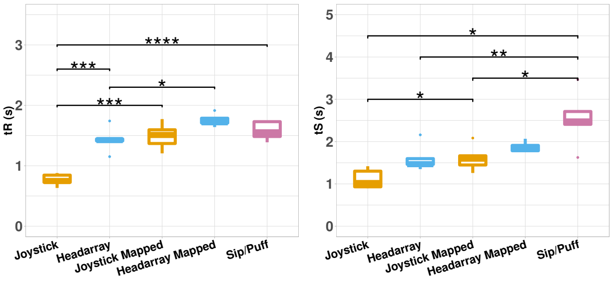
2) Protocol: The pilot study was conducted with five lab members, and each subject performed the trajectory and command following tasks under five interface conditions: joystick normal, joystick mapped, headarray normal, headarray mapped, and sip/puff. The order of task conditions were randomly balanced across subjects. The performance metrics used for analysis were selected from previous work [1].

III. RESULTS AND DISCUSSION

In Figure 2 we see that there are significant differences between the sip/puff device and joystick, and sip/puff and the joystick and headarray in terms of the number of times participants broke the path barrier (nBB) and the total percent of task time that the participants were not fully within the path bounds (tOB), respectively. However, when the three interfaces are mapped the same way, there is no longer any significant difference in the trajectory following performance measures.

In Figure 3a, we see significant differences in response times (tR) between the joystick and the headarray and sip/puff device. However, when the interfaces are mapped similarly, there is no longer any significant difference in tR. On the other hand, in Figure 3b, we still see significance in settling times (tS) even when mappings are similar. This suggests that even though tR is affected by how the user input is mapped through the interface, tS is more dependent on how the user inputs command to the interface.

For a person with full upper limb control, the joystick interface is commonly the easiest interface for issuing commands. However, when the joystick mapping is similar to the limited sip/puff interface, the usage measures were comparable, even though issuing commands through the sip/puff device is more difficult. In the mapped paradigm for all three interfaces, depending on whether you are in the rotation or translation mode, a specific *user input* (i.e. pushing the joystick forward or pushing air out of the straw) will map to two distinct *control inputs* (i.e. forward versus turning right). This one-to-many mapping may be adding an extra cognitive burden that supplants the physical ease of using the interface.



(a) (b)

Fig. 3: Command following. (a) Response times (tR) (b) Settling times (tS).

Since we see these differences in the nBB, tOB, and tR performance measures when using the same interface that has been mapped differently, our next step is to determine which features of the interface impact which usage characteristics. The features that we will investigate are (1) proportionality of input, (2), continuous vs discrete input, (3) dimensionality, (4) mode switch method, (5) number of mode switches to cover full control space, and (6) method of input.

The results of this study will help us design an interface-aware shared-control paradigm where we do not need to specify an interface type (e.g. joystick), but instead we specify features of an interface. This will help formulate the framework in such a way that it is more general and applicable, especially since many interfaces such as the headarray and sip/puff are programmed and mapped in different ways to suit the individual needs of the assistive device user.

IV. CONCLUSION

In this study we showed that when different interfaces are mapped the same way, even if the form of user input is materially different, many performance measures are comparable. Our future study will look at the importance of different features of the interface mapping on performance measures.

ACKNOWLEDGMENT

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