Six-button Click Interface for a Disabled User by an Adjustable Multi-level Sip-and-Puff Switch

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Abstract

There are various ways to control a computer, but today the mouse function, to move a cursor and to perform a click function, is essential. For motion-disabled persons, especially persons with high spinal cord injuries, special aids are needed to perform these interactions. In this study, an alternative way to perform a click function has been investigated, the sip-and-puff function. The purpose of the study was to improve an existing equipment used for click function, a sip-and-puff unit. An user-centred design approach was used, which means that the users took an active role in the development process, testing the prototypes in each development step and providing input for improvements. A survey of existing sip-and-puff units were performed, and from this and successive tests with the users, a sip-an-puff system was developed. As a result, a six level sip-and-puff unit to control a computer was developed. It was shown that spinal cord injured with high neck injuries could control a computer by using a multi-level sip-and-puff and that they could control the computer faster when they used a multileveled sip-and-puff instead of using a traditional sip-and-puff that only had two levels.

Categories and Subject Descriptors (according to ACM CCS): H.5.2 [Information Interfaces and Presentation]: User Interfaces—Input Devices and Strategies

1. Introduction

The computer has become an important and much used tool in our every day life. The computer is also used and appreciated tool in school, at work and at leisure. For people who are motor impaired, the computer can be the aid, which help them, handle their everyday life [LZ05]. The computer has as a technical aid given disabled persons greater opportunities to perform meaningful activities, such as writing, reading and communicating [RZ04].

Motor impaired people have with the help of Information Technology been given great opportunities to a more independent life and thereby a higher quality of life [LLS04] [JS96]. This also applies to people with high neck injuries [DHW*04].

For people with these kind of injuries, it is very hard, or sometimes impossible, to use traditional keyboards or mice, to control a computer. Therefore, people who only can use head movements to control a computer need alternative computer interfaces. Since the mouse function is regarded as more important than text input with graphical interfaces [ZM98], alternative ways to achieve a mouse function has been investigated.

For people with high spinal injuries, but who still can move their heads, several alternative steering facilities are available; steering through the face [Bra98], the head [CCKL03], the voice [IH01] and the eyes [SAC*07]. There is also a possibility to control the computer through technologies that doesn't demand any rotation of the head, like steering with your breath [Ori10], brain waves [PKSK03], the jaw [Spi10], the lips [Lif10], the pupils [EIIM10], the tongue [Nor05] and the teeth [SBGP08].

For the head controller, there are a number of different technologies to choose from to control the cursor; camera [BGF02], ultrasound [NE02], infrared [CTC*01], and motion sensors [GL06]. All techniques have their advantages and disadvantages that need to be consider on choosing the solution.

Something that is easily forgotten when choosing technical aids is that the equipment at a long term can cause cumulative trauma disorders. People who often use a traditional mouse can get troubles with their arms and hands, a so-called mouse arm [Vib10]. Such problems from upper limbs and back/neck have been reported on disabled people who used their computer equipment for some years [SS04]. These inconveniences are most likely to be related to the relatively unilateral load some custom controlled computers provides, and also on the unergonomic and static sitting position and posture, with high loads on the neck and back.

It is therefore important that the equipment is gentle for the user and fits the user's needs and abilities. One advantage is if it is possible to switch between different devices.

One way to do this is to combine different technical aids to obtain the best solution for the individual. The functionality of the mouse can be divided into the cursor control and the click part.

Mouse clicks can be achieved; with a sip-and-puff, with software that provides an automatic clicks when the cursor is held still for a certain period of time, with eye blinking or with the eyebrows.

For many disabled people with high spinal cord injuries, a head controlled mouse, moving the cursor, with sip-and-puff as a click function, is a common combination. For example, two short sips can correspond to a double click, whereas sucking and then keeping your breath can correspond to a click-draw function.

The purpose of this paper was to examine how a regular equipment to control a computer can be improved with special emphases on the user-interface. The idea was to improve a working aid based on the special needs and requirements of people with high spinal cord injuries. It was also desirable that the device should be useful for as many as possible.

2. Methods and materials

A sip-and-puff, as in Figure 1, is a well-known technical aid for the target group, which also has proven not to cause any loads for a long-term user.

A sip-and-puff unit as a click function can be combined with various systems to control the computer cursor.

An Internet survey was made over which sip-and-puff units that exists on the market, what they were used for and their functionality. Data for approximately 20 units were compiled. The sip-and-puff units are mainly used to control computers or motorized wheelchairs, but also to control different types of motor vehicles, sailing boats, environmental control, to control page-turners, and more.

Most sip-and-puff units have only the features sipping and puffing, which corresponds to two functions. There are also devices with only sipping or puffing, respectively. The more

Figure 1: *A sip-and-puff device.*

advanced had four functions, two levels of sipping and two levels of puffing [Gew10]. There are also units for lip control, that has a sip-and-puff integrated, but they only have two sip-and-puff functions [Lif10]. What mainly distinguish the units, are their attachment and their appearance. However, their functions are very similar. Some different units from the survey are listed in Table 1. As the majority only had two functions they are presented by "standard sip-and-puff" in Table 1.

Name	Sip	Puff	Other
Standard sip-and-puff	1	1	-
Gewa 5500 SB-4H	1*2	1*2	Two levels
Jouse2	1	1	Cursor control
IntegraMouse	1	1	Cursor control
Permobil 1820361	1	1	Cursor control
Sip & Puff Mouth Joystick Game Controller	3*1	3*1	4 lip buttons

Table 1: *Sip-and-puff overview.*

The investigation showed that there are many users who wished for double or triple sip-and-puff connections in order to better control the computer. Instead of a sip-and-puff with many different levels, the wanted several 2-functional sip-and-puff units parallel. Many times it was used to increase the ability to play games.

Three users of a sip-and-puff and two helping equipment prescribes were interviewed. The users, who all had spinal cord injuries, thought that the sip-and-puff as a clicking unit worked well, but they were sometimes forced to use two units' two control two different things. This meant that the users had

to have two mouthpieces in front of them. A request of only using one mouthpiece with the same functionalities came up. The prescribes recommended to have a variable sensitivity of the sip-and-puff unit, since the capacity of sip and puff can vary enormously between individuals, and especially disabled persons.

After that the actual development work of the sip and puff unit started. A user-centred design approach was used [Bö00], which meant that on the basis of the surveys and the interviews with the users, a first prototype was developed and tested by the users. The users were interviewed and opinions were addressed and after adaptation, a new test period began. This was repeated until there were no more complaints left or the remaining complaints were of minor importance.

The most common way to construct a sip-and-puff unit is to take a pressure sensor and then decide the pressure level for contact changes for sip respectively puff. That means you put the values 0 or 1. Since most pressure sensors are analogue, it corresponds scaling an analogical sensor to a digital two level function. There is no limitation in how many levels the pressure sensor itself can discriminate, but it can be difficult to control too many sip and puff levels as a user.

For maximum freedom and control of the development process, the entire sip-and-puff unit was constructed from scratch, both hardware and firmware. The sip-and-puff unit is relatively simple in its design and consists basically of a pressure sensor (from Analog Devices) and a microcontroller with flash memory and USB support (from Microchip). In this case the USB human interface device (HID) class was used. The USB HID class is used for devices like mice, keyboards and other similar devices. Therefore the sip-and-puff unit acts like a regular mouse and no USB driver needs to be installed on the computer.

The first prototype hade five levels on both the sip and puff function (10 functions). At the first field test, the pre-programmed values of the sip and puff turned out to be completely misaligned for the disabled users. A disabled person with a high neck dysfunction does not have the same muscular strength and control of his body as a person who is fully able to move. Therefore came the conclusion that the users themselves had to be able to tune in the levels.

For the second field test a computer program was developed, where the users themselves could set the values for the sip-and-puff levels. In discussions with the users, it appeared that they wanted a sliding scale that they could tune in after their own mind. It proved though that the user had some difficulties tuning in the levels themselves. A practical test showed that most users did not use all 10 functions and that they also thought it was too hard separating so many levels since the difference in air pressure became pretty small.

From prescribes side came a request to tune in the level both by a sliding scale and with entering a number. This number should be possible to save in order to reset to normal adjustment for a certain user. It is also easier to remember a setting this way. Therefore a saving function was installed so you could keep your old settings for the future, in case you changed computer.

Changes were introduced taking to consideration of the opinions that had been expressed, which resulted in the number of levels being changed to only three, as seen in Figure 2. It turned out that even three levels could be too much, so therefore a function where you could choose between 1, 2 or 3 levels of sip and puff were implemented. The sip and puff settings are independent, so it is possible to choose one sip level but three puff levels. It is also possible to completely shut off one function by simply choosing 0 sip or puff levels.

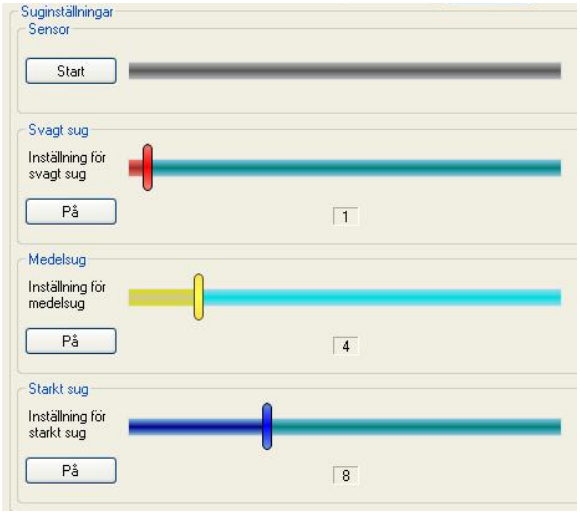

Figure 2: *Sip-and-puff software parameter settings.*

It turned out that the settings were still a problem for the user and that they wished for an easier way to set the levels. Therefore an auto setup function was installed, (the grey slide bar) where the user sips light (red), medium (yellow) or hard (blue) and then the levels are set automatically, and the puff function is set in the same way. The advantage of the auto setup is that the levels are individual adapted to the user.

When the users could adjust the equipment to the right levels on their own, a request came up to also be able to set which clicking function every level should correspond to. Therefore, also this functionality was implemented, as shown in Figure 3.

It turned out pretty quickly that the users also wanted the possibility to choose other functions than those existing on a regular computer mouse. Wishes to be able to generate keyboard strokes emerged, which was also implemented in the software. After that, script-functions were implemented. The more commands the users could make, the quicker the computer can be controlled.

Figure 3: *Click and sound setting menu.*

When more functions to choose between were available, the need to certify which sip or puff level you had chosen became apparent. Therefore sounds were added to each pressure level. Relatively quickly it came clear that you also needed the option to turn the sound off, so that feature was immediately implemented. It turned out that the users themselves wanted to decide which sounds that each level should have, and therefore this feature was introduced. There was also a request to choose your own sound. That feature was also introduced but since it needed a certain handling before you could get the sound, few actually used that function.

3. Results

A six level sip-and-puff unit to control a computer was developed through a user centred developing process. A user centred design process leads to close interaction with the users, which results in a big commitment, and good response during the field tests. The users were a part of the entire developing process that lasted for about 3 months.

The unit is connected through the computers USB port and powered through the USB port. No software needs to be installed on the computer to be able to use the device. However, software needs to be installed if you want to change the settings. The settings are saved in a memory in the unit, which makes it possible to move the unit between different computers without having to reset it.

The users can set the air pressure levels for the sip-and-puff device individually for each level and choose which feature it should have. The settings of the device are made through an installing program so that the user can set the levels easily on their own. In the installing program, the user can plug in different features and sounds to each level and save their own settings.

An analysis of the saved setting files showed (unsurprisingly) that different users had set different settings on the pressure levels. More interesting was that the users had different settings on both the sip and the puff levels. In comparison with non-disabled people, the levels were low.

The users could control the computer faster when they used a multileveled sip-and-puff instead of when they used a traditional sip-and-puff that only had two levels.

The developed sip-and-puff unit could be used with other equipment to control a computer. The sip-and-puff unit could be combined with tools that gave control of the mouse as mouse buttons to give clicking functions, and more. The device could also be used with existing tools as a complement to these. There was no problem in using the device along with traditional mice and keyboards. The subjects in this study were all pleased with their new sip-and-puff device and wanted to keep it after the trial period was over.

4. Discussion

The aim to produce a gentle tool through improving an existing product worked out well. Cumulative trauma disorders is a problem for users who spend long shifts for a long period of time in front of the computer. It is therefore essential that the tools are easy and ergonomic to use and that you can choose between different methods to control the computer. You have to consider both the individual's functional requirements but also to consider the environment. Likewise, it is advantageous if the users have different control methods available, so that they can switch between them.

A good aid helps, but it is also important to consider the user's posture during the computer work, since many of the users are in wheelchairs when the computer is being used. The manual wheelchair is originally developed to be an effective transportation tool and is not always the best seating for computer use.

Something to investigate further is how the sip-and-puff unit would work together with software for cursor control. There is a group of disabled people who just have a clicking feature and control the computer through that along with the software that provides the cursor control. Would they be helped by a multi-level sip-and-puff where they currently only use a two levelled?

5. Conclusion

In this study, a multi-level sip-and-puff unit was developed with a user centered design approach. The unit was especially developed to be used as an aid for spinal cord injured. It was found that the users could control a computer faster when they used a multileveled sip-and-puff instead of when they used a traditional sip-and-puff that only had two levels. It was also found, that the sip-and-puff unit was appreciated by the user group.

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