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GNomon: Enabling Dynamic One-Switch Games for Children with Severe Motor Disabilities

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Abstract

Nowadays, video games represent one of the most popular forms of structured play. They allow children to enjoy very entertaining game mechanics, a variety of game genres and novel modes of interaction. However, this is not always the case for children with severe motor disabilities that rely on one-switch interfaces to access electronic devices. This work in progress presents GNomon, a framework based on the NOMON interaction modality which enables the creation of dynamic, entertaining and complex one-switch video games for children with severe motor disabilities. The framework was designed in close collaboration with a team of speech therapists, physiotherapists and psychologists from one of the Local Health Agencies in Turin, Italy. We also report the design and implementation of two GNomon-based games, which have already been accepted by the health agency experts to be tested with a group of their assisted children.

Author Keywords

Accessible games; One-switch interaction; Assistive technology; Children with disabilities; Single switch selection

ACM Classification Keywords

H.5.2 [Information interfaces and presentation (e.g., HCI)]: User Interfaces - Graphical user interfaces (GUI);

K.4.2 [Computers and society]: Social Issues - Assistive technologies for persons with disabilities.

Introduction and Background

The ability to play is one of the most important during childhood, as play is the leading source of development in the early years [6]. Play comes mainly in two forms: structured or open-ended. Most games fall under the category of structured play and are different from open-ended play mainly because a game defines clear rules and goals. Video games, in particular, are becoming a ubiquitous part of many children's lives in the United States and recently in many European countries (see the statistics reported in [4] and in [1], respectively), as these can be played on increasingly more electronic devices, such as game consoles, computers and smartphones. Moreover, modern video games offer dynamic game mechanics, a wide variety of game genres and novel modes of interaction that make them an entertaining and challenging experience for children to enjoy.

However, this is not always the case for children with motor disabilities. These children cannot play most of the available commercial video games as these are usually very fast to be controlled with custom controllers or with alternative switch interfaces. In addition, little attention has been paid to developing Universally Accessible Games [3] as dynamic as mainstream video games. Even though, studies (such as [5]) show that children with motor disabilities want to play dynamic fast-paced video games similar to those played by their peers without disabilities.

Children with even more severe motor disabilities usually have to communicate through a single gesture such as moving a finger or tilting the head, therefore they can only rely on the use of one-switch interfaces for accessing

electronic devices. The problem is that one-switch input is limited to just a "click" with timing information and often it is not sufficient for allowing these children to access challenging and dynamic video games. In fact, after reviewing several free games (from a popular website¹) that can be played with just a single switch without requiring information about the click duration, we identified three major categories of one-switch video games and the main barriers that prevent children to enjoy them:

1. *Action/Reaction games*. The goal on these simple games is to press the switch to obtain some effect (e.g., when the switch is pressed, a football player kicks a ball). These games are used to teach the children how to use the switch and to associate it to a trigger for different actions. The downside of many action/reaction games is the lack of interactiveness for cognitively able children due to the fact that they cannot make any decision to affect the outcome of the game after pressing the switch.
2. *Scanning based games*. Scanning allows the selection of an element from an arrangement of selectable elements with a single input event. It works by sequentially highlighting the selectable elements (or groups of elements) and waiting a short time on each of them for an input to occur. An element is selected if it is the one currently highlighted when the input event occurs. Most of the available one-switch games (e.g., chess, memory, battleship, etc.) fall under this category. These are usually more complex than action/reaction games as scanning allows to select

¹<http://www.oneswitch.org.uk>, last visited on January 2, 2015

more than one element (or action) from an arrangement of options. However, it is not possible to interact with every game through one-switch scanning. For it to be feasible, the game must have a *static* arrangement of selectable elements, it must be possible to establish a fixed scanning order and the game mechanics have to allow enough time to make a selection even after a complete scan.

3. *Click timing games*. This category of one-switch games includes those in which the player has to press the switch with high precision to perform an action in a very specific moment. The problem with many of these games, such as Poto & Cabenga and Strange Attractors, is that they are not fully accessible to children with severe motor disabilities because the games require a speed and precision that the children do not have.

The objective of this work in progress is twofold. First, we propose GNomon, a framework that provides specific functionalities to enable the creation of accessible video games for children with severe motor disabilities which interact with electronic devices through a single switch, only. The second goal is to present two GNomon-based games designed in collaboration with a group of healthcare experts and already implemented for future validation with children with severe motor disabilities.

GNomon

GNomon is a framework that enables the creation of accessible and dynamic one-switch video games. It is based on the NOMON one-switch mode of interaction, which allows to select one of many elements from the screen without extra special hardware (e.g., expensive eye trackers) and without requiring them to be arranged in any particular configuration or to be stationary.

In a very inspiring publication [2], Broderick and MacKay present in detail the operation and evaluation of NOMON, therefore we report just the main aspects of its operation here:

- NOMON associates a small visible clock face to each selectable element on the screen and places it next to the element.
- Every clock has one black hand which rotates at the same speed as the other clocks' hands, but with a different phase. The clocks also have a red hand fixed at "noon".
- To select an element the user has to find the associated clock and try to press the switch, as precisely as possible, when the black hand is crossing the red hand at noon. Then, for each clock NOMON calculates the probability of being the intended selection, given the clicks thus far. If the probability of a clock is sufficiently high but not enough to declare it as the selection, the clock face turns yellow and a new round starts. Finally, when the probability of one clock reaches a predefined threshold, it turns green and the associated element gets selected.

The GNomon framework incorporates our custom extended C# versions of the original NOMON Python libraries into a Unity2D plugin. In particular, the framework provides functionalities for creating sets of selectable game objects with associated NOMON clocks for enabling dynamic point-and-click game mechanics using a single switch. These sets can be resized at any time by adding or removing elements, which is necessary for supporting common dynamic game actions such as the creation of new items or the destruction of characters. Moreover, the selectable game objects do not have to be

fixed in predetermined positions on the screen and they can move freely without compromising the effectiveness of selection. This is very useful to make dynamic games that have moving elements, but also to make static games (e.g., the memory game) more challenging by allowing selectable elements to be displayed without layout restrictions.

A participatory approach was adopted for eliciting the features and accessibility guidelines of GNomon, thus we worked in close collaboration with a team of speech therapists, physiotherapists and psychologists from one of the Local Health Agencies in Turin, Italy. They actively supported us by guiding important design choices and proposing features on behalf of the children with severe motor disabilities assisted by them. In total, we conducted five iterations of meetings with the experts for testing and collecting suggestions to improve the framework. Thus, several features of GNomon, mainly related to specific accessibility issues, were adapted to follow their valuable recommendations. Some of these recommendations are the following:

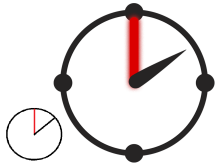


Figure 1: This figure shows an example of the clocks used in GNomon for selecting game objects (right) and the original NOMON clock (left). The appearance of the new GNomon clock is based on the original design but with important modifications suggested by the experts: enlarging the clock, thickening all clock lines, placing marks at clock quarters, rendering more eye-catching the red noon and making the moving clock hand pointier.

1. Providing additional indicators for facilitating interaction. In particular, four circular marks were placed in the clock quarters (the three o'clock, six o'clock and nine o'clock) to facilitate the interaction of children with long muscular latent periods (i.e., the time elapsed between the movement command and the muscle movement) by helping them with indications of when to start "preparing" themselves for pressing the switch.
2. Making the clocks more eye-catching. Game objects are usually attractive, colorful and animated, hence they tend to concentrate the attention of children.

Moreover, as the clocks are just the means for selecting game objects, it is normal that the former are less striking than the latter. However, the clocks' appearance was redesigned to be as eye-catching as possible (while keeping its simplicity) to prevent the less attentive children from ignoring the clocks. In particular, the clocks were enlarged, the colors were made brighter and more contrasting, the lines were thickened and the moving clock hand was made pointier. Figure 1 shows the new appearance of the clocks.

3. Reducing the average speed of rotation of the moving clock hands and making it customizable. The rotation period of the clock hands ranges from 1 to 10 seconds, to allow children with long muscular latent periods to enjoy GNomon based games. The rotation speed can be set and changed easily by the children or by their caregivers.
4. Giving auditory and visual feedback when a clock is selected. Besides the specific feedback and the actions triggered in each game when a clock is selected, the clock itself changes color and a sound is played.

The Games

Two prototype games with different degrees of difficulty which are fully playable with just one switch were designed in collaboration with the local health agency. Both games have already been accepted by the experts as suitable to be introduced to the children that they assist. We report them here.

One Switch Ladybugs

The first game is One Switch Ladybugs, a simple action/reaction video game that allow children with severe

motor disabilities to make one of four ladybugs jump. Each ladybug has a different color and provides a unique auditory and visual feedback when it is successfully selected. There are no scores or time constraints of any kind because the game has been designed mainly to explain how the clocks are operated and how selection works. This particular game can be implemented with scanning, but it was developed based on GNomon to demonstrate its potentialities also with fixed layout games. Figure 2 shows a screenshot of the game.

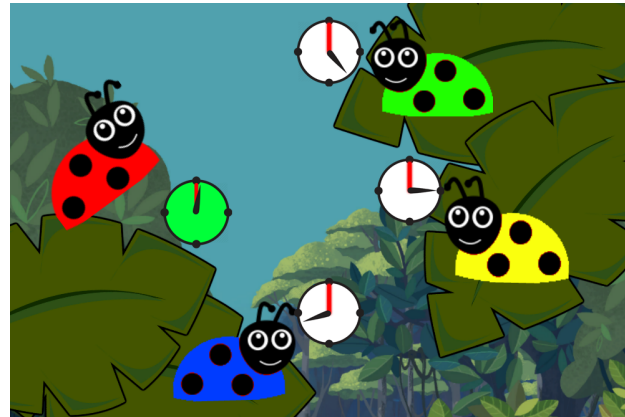


Figure 2: One Switch Ladybugs screenshot. The figure shows the red ladybug (top left) jumping while it is being selected.

One Switch Invaders

One Switch Invaders is more complex than the previous game and cannot be classified under any of the aforementioned categories of one-switch video games. This is because it is a *dynamic* one-switch game that does not require accurate timing or clicking precision. This is a game without a fixed layout, in which multiple selectable elements (aliens), moving around the screen, have to be selected with a time constraint (i.e., before they touch the

ground). The implementation of One Switch Invaders is not feasible by applying scanning or other one-switch interface because the elements are not static in predefined layouts and it is not possible to establish a scanning order without negatively affecting the game mechanics.

The game objective is to score points by killing the aliens before three of them touch ground. There are aliens of five colors which constantly fall down the screen at random speed. Each alien is associated to a clock to enable its selection and is generated in a random position at the top of the screen. Figure 3 shows a screenshot of the game.

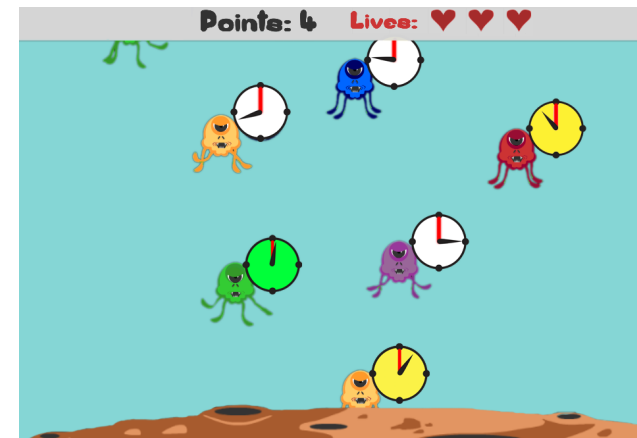


Figure 3: One Switch Invaders screenshot. The figure shows six aliens falling down the screen while the green one (at the left) is being selected.

Expert Recommendations

Finally, we also present the main recommendations made by the local health agency experts regarding the two prototype games:

- The appearance of each game object (ladybugs or aliens) must be unique. This helps the children to remember the game object that they are trying to select if they lose track of it. For the ladybugs, this was achieved by assigning them four different colors and placing them in the four quadrants of the screen. However, in the case of the aliens this is not possible because there is not a predefined number of aliens that can be on the screen at the same time. Therefore, the solution adopted in the second game was choosing five colors to be sequentially assigned to each new alien. In this way, children that lose track of their game object can retrieve it without being confused with another near object that looks the same.
- Different game objects have to produce different visual and/or acoustical feedbacks when selected.
- Although aliens can fall with different speeds, the maximum falling speed has to be bounded by a maximum value set by the player or the caregiver.
- In the One Switch Invaders game, the aliens wait until the first “click” to start falling. In this way, the player can observe the clocks and familiarize with the speed of rotation of the clock hands before trying to select one of them.

Conclusions and Future Works

This work in progress proposes GNomon, a framework that enables the creation of one-switch video games for children with severe motor disabilities. Moreover, it also presents the design and implementation of two prototype video games with different characteristics, based on GNomon. The development of the framework and the

games features was carried out in collaboration with a team of experts from one of the Local Health Agencies in Turin, Italy.

Future works will consist in evaluating the usability, accessibility and playability of video games based on GNomon. Currently, the two games reported on this work in progress have already been accepted by the experts of the health agency as suitable for being introduced to the children. The games will be validated with an initial group of 10 children with severe motor disabilities that rely on one-switch interfaces to access electronic devices. The tests will take place in Turin, Italy, in early 2015.

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