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Clocks, Bars and Balls: Design and Evaluation of Alternative GNomon Widgets for Children with Disabilities

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Abstract

Children that rely on the use of single switches to access electronic devices, due to physical impairments, can play dynamic video games as their normally developing peers thanks to GNomon: one of the first framework for creating dynamic one-switch video games. However, children with physical impairments that also have cognitive disabilities find additional difficulties in using the current GNomon-based interface. To compensate these difficulties, the "classical" GNomon widget must be rethought and simplified. This paper proposes a parallel between three different widgets specifically designed for GNomon-based interfaces. Each widget employs metaphor in a different way and it has been evaluated with six children with motor and cognitive disabilities. The results are encouraging: a widget, based on the "big and small" concept, is preferred by children and is a candidate to make single-switch games easier to approach.

Author Keywords

Accessible Games; Usability; One-Switch Interaction; Children with Disabilities

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

Video games have become part of popular culture to the point that every single child was born into a world where these are a fact of life [6]. Moreover, video games are no longer just an entertainment media but they are important tools for education and development of social, emotional and cognitive skills, especially during childhood [7]. Despite this, children with disabilities encounter many barriers that prevent them from playing video games as their normally developing peers. In particular, children with severe motor disabilities, which rely on one-switch interfaces to access electronic devices (e.g., children with cerebral palsy), have been long excluded from enjoying *dynamic* video games, since these are played with complex input devices such as game controllers, mouse or keyboard. Typically, one-switch interfaces are based on scanning interaction, which allows the selection of one element at a time from an arrangement of selectable elements in sequential order (see [3] for more details about how scanning works). Unfortunately, scanning-based interfaces have been developed having in mind text entry or menu selection, thus they are not suited for dynamic game interaction. In fact, while dynamic games are fast-paced and require rapid decision-making and timely responses from the player, a scanning selection mechanism is not intended for time-dependent tasks and it is suitable for contexts with the following characteristics:

- Large selection sets in which the probability of having to repeat an input is low.
- Known and static selection sets.
- Selection sets in which the elements are arranged in fixed positions to enhance selection speed and effectiveness.
- Selection sets in which every element has a computable probability of being the next to be selected, given the previous selections.

Nevertheless, the recent development of GNomon offers the unique possibility of making accessible dynamic video games playable with just a single switch by children with severe motor disabilities. GNomon is described for the first time by Aced López et al. in [1] as a software framework which provides the functionalities to enable the creation of dynamic point-and-click game mechanics, using a single switch. It is based on the NOMON one-switch mode of interaction [5], which allows to select one of many elements from the screen without extra special hardware (e.g., expensive eye trackers) and without requiring them neither to be arranged in any particular configuration nor to be stationary. In a nutshell, the original operation of the selection mechanism at the base of GNomon works like this (see also Figure 1):

- GNomon associates a small widget in the form of a clock face to each selectable element on the screen.
- Every clock widget has two clock hands: a red hand fixed at noon and a black clock hand that rotates with the same speed in all the clocks, but with a different phase.
- To select an element the user has to look its associated clock and try to press (click) the switch, as precisely as possible, when the black hand is crossing the red hand at noon. Then, for each clock, GNomon calculates the probability of being the intended selection, given the clicks thus far. If the difference of probability between the two most probable elements does not reach a predefined threshold, a selection

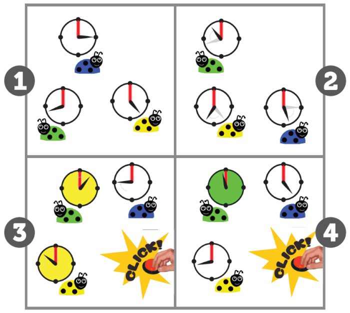

Figure 1: This figure illustrates the operation of GNomon. 1) First, every element has an associated clock widget. 2) All the clock hands rotate at the same speed and with different phase. 3) The user activates the button and the probability of being the selection is calculated for each clock, those with the highest probability turn yellow. If there is not a winner, a new round starts again and clocks with similar probability of being the selection are assigned new and contrasting phases. 4) Eventually, the difference of probability between the two most probable clocks becomes large enough to declare a winner, which signals it by turning green.

is not performed and the clock widgets with a sufficiently high probability (but not enough to be selected) turn yellow. Finally, when the difference of probability between the two most probable elements is large enough, the widget associated to the element with the highest probability turns green and gets selected.

In the studies presented in [2], Aced López et al. evaluate the playability of three GNomon-based games with a group of eight children with severe motor disabilities.The remarkable conclusion is that dynamic video games based on GNomon are playable by children with severe motor disabilities with just a single switch, as these games are learnable, satisfactory, effective, memorable and fun.

However, the aforementioned results showed that children who also had cognitive disabilities, besides the motor impairments (e.g., participants with cerebral palsy or multiple disabilities[1]), had more selection errors and found much more difficult to use the GNomon widgets than the children with just physical disabilities (e.g., participants with spinal muscular atrophy). In fact, children with cognitive disabilities often have difficulties with attention, reasoning, perception and self-regulation (as described in [9]); hence, it is normal that some children with severe motor disabilities that also have some degree of cognitive impairment found a barrier while using the normal GNomon clock widget. In particular, while a person without cognitive disabilities fixes her sight on the fixed handle and clicks whenever handles overlap, the children involved in the previous study tend to follow the moving handle, continuously, according to the psychologists and the speech therapists involved in the study. This causes an augmented cognitive effort and a consequent fatigue in using such an interaction mode. To overcome this barrier, new widgets needed to be designed to make the Gnomon-based interface more usable, accessible, and fun to experience for a larger number of one-switch players.

The Widgets

The GNomon framework had "inherited" its original and characteristic clock widget from the NOMON interaction modality, on which it is based. The design of the clocks was already adapted by Aced López et al. [1] from its original version following the accessibility guidelines elicited with a group of speech therapists, psychologists, and physiotherapists that work every day with children with multiple disabilities. In fact, it is possible to change widgets without changing the normal operation of GNomon. It is enough to design an object (the *selector*) capable of changing in form, position, scale, rotation or color, and to provide the user with an indication of the optimal moment to press the switch (the *indicator*). Likewise, it is important to have a different color version of the widget to highlight the elements that have a high probability to be not yet selected. In the case of the original clock widget, the selector is a black clock hand that rotates continuously and the indicator is a red clock hand fixed at noon, which flags that the optimal moment for pressing the switch is when the selector crosses it. The highlight version of the classic clock is the same as the normal version, but with a yellow face.

For this study, three widgets were designed in a participatory design session with a group of speech therapists and psychologists of one of the Local Health Agency in Turin, Italy, which have a daily experience with children with motor and cognitive disabilities: a clock, a bar, and a

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[1] Although the "multiple disability category" represents a heterogeneous group in terms of impairments as well as functioning and behavior according to [4], children with multiple disabilities share severe deficits in motor, cognitive and sensory skills in different degrees.

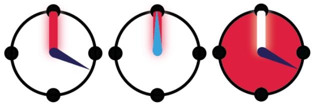

Figure 2: From left to right: normal clock widget, normal clock widget with reinforcement, and highlighted clock widget.

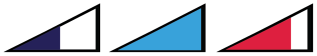

Figure 3: From left to right: normal bar widget, normal bar widget with reinforcement, and highlighted bar widget.

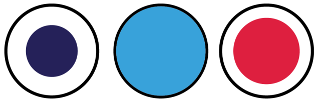

Figure 4: From left to right: normal ball widget, normal ball widget with reinforcement, and highlighted ball widget.

ball. All of them employ metaphor in a different way and consist of three parts: a selector, an indicator, and a third element to reinforce the optimal moment for pressing the switch (the *reinforcement*). The colors of the three widgets were chosen to provide maximum contrast in their normal and highlighted versions, to help children with vision difficulties. The chosen color palette is the following: White, Black, Red (#DC1E3E), Dark Blue (#201D5A) and Light Blue (#3EA2DA).

The Clock
This widget is a slightly different version of the classic GNomon clock widget, a legacy from the original NOMON interaction mode. The differences are minimal and related to the colors, only: the normal clock widget did not take into account any consideration about providing the maximum contrast possible. In particular, the selector is now dark blue and turns into light blue while is crossing the indicator, as reinforcement; the highlighted version of the clock is no longer yellow, but red with a white indicator. The clock widget is illustrated in Figure 2.

The Bar
This widget was designed to replace the concept of rotation that is used in the clock widget, with the “full and empty” metaphors, which should be cognitively easier to grasp by the target children, according to the Griffiths Mental Development Scales [8]. The selector is a triangular bar that fills (from left to right) and empties (from right to left) a triangular frame. The indicator is a thick black line at the right end of the triangular frame, which flags that the optimal moment for pressing the switch is when the selector is filling completely the frame. As in the clock widget, the reinforcement is the color change of the selector from dark to light blue when it reaches the indicator and the highlighted version of the widget has a red selector. Figure 3 presents the bar widget.

The Ball
This widget tries to improve the usability of the interface through the “big and small” concepts, which should be cognitively easy to understand for the target children, according to the Griffiths Mental Development Scales [8]. It uses a ball selector that expands and decreases in all directions. The indicator is a circular frame: it suggests that the optimal moment for pressing the switch is when the ball expands until it touches the frame indicator. The reinforcement is the color change from dark to light blue when the ball is at its maximum size and the highlighted version of the widget uses a red ball as the selector. The ball widget is presented in Figure 4.

Evaluation

The three widgets were evaluated through a one-session test with six children with motor and cognitive disabilities, in collaboration with one of the Local Health Agencies in Turin, Italy. The evaluation aimed at assessing the errors, the efficiency, and the satisfaction associated with each widget.

Participants
The participants of the study were six male children between 4 and 8 years old diagnosed with Cerebral Palsy (CP), which rely exclusively on the use of single switch interfaces to access electronic devices. More importantly, all the children have a mental age between 3 and 5 years old. Six months earlier, four of the participants took part in the playability evaluation of the first two GNomon games presented in [2], obtaining the four lowest performances. The Local Health Agency experts were in charge of recruiting the children and fixing the evaluation dates.

Materials and Methods

The tests were conducted in Italian at the Local Health Agency, to avoid making some children anxious about being in an unfamiliar place. A speech therapist (acting as the tester) held the sessions and kept the participants motivated along the evaluation, while two observers (one HCI researcher and a speech therapist) carefully took notes. It was decided to have a speech therapist as the tester because she knows how to communicate more effectively with the children (in particular with non-verbal children) than HCI researchers. All the tests were video recorded with the children faces hidden, with the exception of the test of P3 that was not recorded, since his parents did not give the authorization. The tests lasted between 10 and 20 minutes, depending on the speed of each child to complete the tasks.

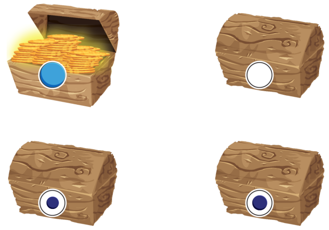

Figure 5: General interface of the tests. The clock and the bar widgets replace, in the same position, the ball widget depicted in the figure.

The evaluation consisted in selecting ten times the only open treasure chest (the one with coins) from a set of four chests, during three trials, one trial for each widget (i.e., clocks, bars, and balls). Each child complete the tasks in a dedicated session, with the tester and the two observers, only. Figure 5 shows the general interface used during the tests with the ball widget. The widgets under evaluation were placed in the middle of the treasure chests to allow their selection. When the correct chest was selected, a sound indicates success and a new game round starts with a new open chest. The children could take as much time as they needed to complete the task with each widget. The tester could end the test early if she noticed that they were not trying to complete the task or if they were inactive for more than 5 minutes. Between each trial with a different widget, the children could take a break to rest, if desired. The children tried the widgets in counterbalanced order, to reduce biases. For each widget, data was collected regarding the moment of selection of the chest, the number of clicks before the selection (hits and misses), and the total percentage of error. Finally, the children were asked for the easiest and the most difficult widgets.

Results and Discussion

The most relevant information collected during the evaluation is summarized in Table 1. The observer notes are not reported here due to space limitations, but they were used to elaborate the discussion of the obtained results.

All but one participant were able to complete the evaluation. The tester had to stop and invalidate the evaluation of one participant because he did not want to continue while he was doing the second widget evaluation. For this reason, we do not include his results. Participants P4 and P5, which had already participated in the playability study of three GNomon-based video games with the lowest performances (see participants P4 and P7, respectively, in the study presented in [2]), were able to perform successfully the selection tasks with all the widgets. After six months without using any GNomon-based interface, they did not remember how to operate the clock widget. Participant P1 did not answer which was the easiest and which was the most difficult widget, but the ball widget had a “rare” effect on him, according to the observer notes taken by the speech therapist: *“the balls concentrated his attention for more than 3 consecutive minutes. . . is the first time I see P1 that concentrated!”*.

The error ratios were calculated as the percentage corresponding to the ratio of *misses* and *hits*, for each widget. A miss occurs when a participant presses the switch without successfully selecting the chest with the coins or without highlighting it. On the contrary, a hit occurs when the participant presses the switch selecting or highlighting the chest with the coins. It is important to point out that consecutive events registered within less than one second are

Participant	Age	Widget Order	Error Ratio (Clock |Bar| Ball)	Task Duration (min) (Clock |Bar| Ball)	Easiest | Most difficult Widget
P1	4	Clock, Bar, Ball	60% | **58%** | 60%	**3** | **3** | 4.5	-
P2	5	Bar, Ball, Clock	63% | 70% | **61%**	4 | 4 | **3**	Ball | Bar
P3	5	Clock, Bar, Ball	59% | 66% | **52%**	7 | 7 | **5**	Ball | Clock
P4	6	Clock, Ball, Bar	**30%** | 38% | 60%	**4.5** | 6.5 | **4.5**	Ball | Bar
P5	8	Bar, Clock, Ball	66% | 70% | **45%**	5 | 6.5 | **4.5**	Ball | Bar

Table 1: Participant age, widget order, error ratio, test duration, and preferred widget as emerged from the test. Best values are highlighted.

discarded. The reason is that the latent periods (i.e., the time elapsed between the movement command and the muscle movement) of these children is always, at least, a couple of seconds. The “task duration” reported in Table 1 does not include the break time between trial of different widgets. The error ratio calculated from the obtained data does not allow quantitative and final consideration about the best widget. No widget, in fact, has a significantly lower error ratio. It may be noted, however, that in most cases (3 out of 5) the ball widget has a slightly lower error ratio. Consistently, the ball widget has a lower task duration in 4 out of 5 cases. Data suggests that all the three widgets are almost equally efficient, being the ball widget slightly higher.

The most interesting result between qualitative data was that all the children named the ball widget as the easiest to use. They preferred the ball widget even when it did not account for the lowest error rate (as in the case of P4), or even if it was used with fatigue at the end of the test (as in the case of P3).

Conclusions

This paper presented the design and evaluation of three alternative widgets for a GNomon-based interface, accessible by children with motor and cognitive disabilities. The widgets consist of a clock, a bar, and a ball. The bar and the ball had been designed around two concepts that require fewer cognitive efforts to be understood than the one employed by the clock. The evaluation of the widgets were conducted with a group of six children with motor and cognitive disabilities and assessed the number of errors, the efficiency, and the satisfaction associated with each of them. The initial results showed that all the children prefer and find easier to use the ball widget, even if it is not always associated with the lowest number of errors.

Future works will consist in a further study to obtain significant results about the design of such widgets. If needed, other widget designs will be explored, with the final goal of make GNomon-based games more usable, accessible, and fun to experience for a larger number of one-switch players.

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