Kinect as an access device for people with cerebral palsy: A preliminary study

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ABSTRACT

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Cerebral palsy (CP) describes a group of disorders affecting the development of movement and posture, causing activity limitation. Access to technology can alleviate some of these limitations. Many studies have used vision-based movement capture systems to overcome problems related to discomfort and fear of wearing devices. In contrast, there has been no research assessing the behavior of vision-based movement capture systems in people with involuntary movements. In this paper, we look at the potential of the Kinect sensor as an assistive technology for people with cerebral palsy. We developed a serious game, called KiSens Números, to study the behavior of Kinect in this context and eighteen subjects with cerebral palsy used it to complete a set of sessions. The results of the experiments show that Kinect filters some of peoples involuntary movements, confirming the potential of Kinect as an assistive technology for people with motor disabilities.

1. Background

Globally, between 2 and 3 children out of 1000 successfully delivered children are affected by cerebral palsy (Krigger, 2006; Reddihough and Collins, 2003; Robaina Castellanos et al., 2007). Cerebral palsy (CP) describes a group of disorders of the development of movement and posture, causing activity limitation (Bax et al., 2005). In most cases, these disorders make essential activities such as communicating or using tools impossible. As a result, the quality of life of these people is seriously affected. Technology has great potential to improve the quality of life of people with CP. However, this potential often falls short because the technology does not fit the specific capabilities of individual users. This has given rise to a research field focusing on the study and development of solutions based on these kinds of user profiles.

Over the years, vision-based motion tracking systems have been used to solve problems related to discomfort and difficulties users have holding devices. With these systems, users movements control a computer without having to press buttons or hold a device. Some studies with people with severe disabilities use a simple webcam to track body features such as the tip of the users nose or finger to provide computer access (Betke et al., 2002), for example to control a video game (Oskoei and Hu, 2009). Other studies detect whether the user is looking at the camera or to the left or right and then send the computer a press button event associated to this eye movement (Magee et al., 2008; 2004). However, these systems need the user to be in a specific position or posture, requiring certain ambient conditions; they also involve complex image processing methods and are usually fairly inaccurate. Several studies have looked into the possibility of using more accurate systems for rehabilitation (Barton et al., 2011; Sandlund et al., 2011), but their cost makes them prohibitive.

In 2010, Microsofts release of the Kinect sensor for XBOX stimulated a lot of new research. Some studies have demonstrated that Kinect can achieve competitive motion tracking performance just as well as other high fidelity optical systems like Optitrack (Chien-Yen et al., 2012) or Vicon cameras (Bonnechére et al., 2014). Other studies have found that Kinect is a sufficiently accurate and responsive sensor for measuring gross movements, making it suitable for stroke rehabilitation systems (Webster and Celik, 2014) or for measuring movement symptoms in people with Parkinsons disease (Galna et al., 2014a,b; Summa et al., 2015). This sensor has shown that it can track body motion with the accuracy required for standard balance tests (Funaya et al., 2013), such as assessing standing balance (Yang et al., 2014). In (Obdrzalek et al., 2012) Kinect was compared with more established techniques for pose estimation using motion capture data. The accuracy and robustness of Kinectś pose estimation was assessed for postures of elderly people in standing and sitting positions. The results were positive, indicating that it could be used for people with CP.

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Most works use Kinect for rehabilitation purposes, not to provide computer access for people with disabilities. Nevertheless, Kinects potential in such activities has been demonstrated, suggesting that it could be used to control a computer. Very few systems have been developed in this field. F.A.A.S.T. (Flexible Action and Articulated Skeleton Toolkit) (Suma et al., 2013) is a middleware software framework for integrating full-body interaction with videogames and other applications. In this system, gestures are configured using expressions as they might be described in a conversation, they are then translated into keyboard or mouse events. AsTeRICS (Assistive Technology Rapid Integration & Construction Set) (Veigl et al., 2013) is a construction set for assistive technologies that allows the creation of access methods for people with disabilities using a large set of sensors and actuators including Kinect. This system provides a graphical editor to create solutions based on a set of inputs and outputs. Although these systems are very flexible, this characteristic makes them too complex for the user to configure. As people with disabilities are becoming accustomed to using Switch devices for computer access and touch tangible devices for interaction, they might not require excessive training to learn how to use Kinect.

Since Kinect is capable of recognizing the twenty main joints of the body with sufficient accuracy, several works like Erazo et al. (2014), Jaume-i Capo et al. (2014), Roy et al. (2013) have used it as an interface to enhance the effectiveness of the rehabilitation of different skills. Most rehabilitation studies use serious games (Michael and Chen, 2006) to make the exercises more enjoyable for users.

Kinect has potential as an access device for those people with CP who cannot access the computer in a conventional way. However, in our review of previous studies, we could not find any studies assessing Kinect as an access device for people with CP; nor could we find research into the behavior of Kinect when used by people with involuntary movements. This study used Kinect as an access device for people with CP; its main goal was to extract valuable information for future research in this field. Hence, in this preliminary study we conducted experiments using Kinect as an event-based access device and used a switch as a reference device. We needed to achieve the following:

- Design an algorithm that transforms Kinect into an event-based device.
- Design a videogame to gather data about user performance using both devices. Although we could have used another type of application, we decided to use a videogame to make the experiments more fun and motivating.
- Study the results to extract information about Kinect as an event-based access device for people with cerebral palsy.

2. System design

The system setup consisted of a PC with Microsoft Windows 7, or higher, the Microsoft Kinect SDK v1.8 package, the Kinect for XBOX 360, or for Windows, and a game structured as shown in Fig. 1. The game contains three main parts that also include different modules:

1. Access method: includes the Kinect sensor, data acquisition, data processing and settings modules.
2. The mechanics of the game: implemented in the Game core.
3. Data collection: generate the results and log files.

2.1. Access method

Although the users have a certain amount of movement control, none of them have sufficiently accurate control to perform a specific continuous movement. Therefore, we decided to design a control system based on discrete events. This access method is often used in software adapted for people with cerebral palsy.

We chose an algorithm based on the speed of a selected joint, either the left hand, right hand or head. Kinect returns the coordinates (x, y, z) of each joint every Δt ms. If X_n is the x coordinate at instant n, then the speed of the joint along the x axis is given by Eq. (1).

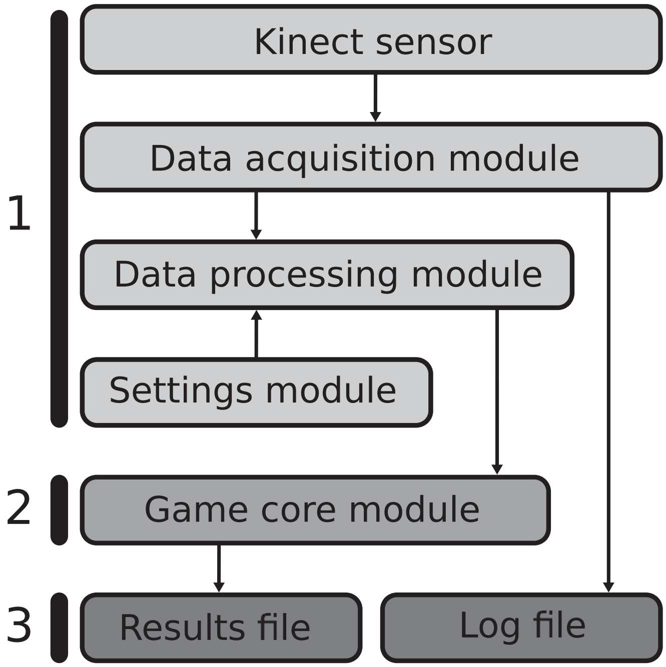

Fig. 1. Game diagram modules.

$$S_x = \left\| \frac{X_n - X_{n-1}}{\Delta t} \right\| \quad (1)$$

The speed in any direction of a specific joint, can be calculated using Eq. (2).

$$S = \sqrt{(S_x)^2 + (S_y)^2 + (S_z)^2} \quad (2)$$

Every time that Kinect returns body values (every 30 ms approximately) the algorithm calculates the speed of the selected part of the body (head or hand) and compares this value with a threshold adjusted to the capabilities of each subject. The minimum value for the threshold was set as the maximum speed at which a user without disabilities can move each body part and the maximum value was set as zero.

Whenever the speed of the movement exceeds the threshold, the system starts a one-second timer with two possible states: stopped, running. A change from the stopped state to running, launches an event similar to a mouse button press. This event shows the system that the user has performed a movement. Another event cannot occur until one second has elapsed.

When a switch is used to control the game and the user presses the switch, the game launches an event and waits until the switch has been released and pressed again to launch another one. The timer described in the Kinect algorithm works in a similar way, preventing the launching of multiple events when the subject is executing a movement.

2.2. The mechanics of the game

As we mentioned earlier, videogames are a great way of getting users involved in experiments, making them more enjoyable. Given that, in the centers collaborating in this study, videogames are commonly used in daily activities, we decided to use this kind of software for our test. In addition, our goal was to check the behavior of Kinect as an access device, we considered that any kind of application was valid for our purposes provided that the application used a habitual access method.

We analyzed several videogames based on discrete events for people with motor disabilities used in both collaborating centers. We were particularly interested in one of these: SEN Switcher (Nothern Grid, 2001).

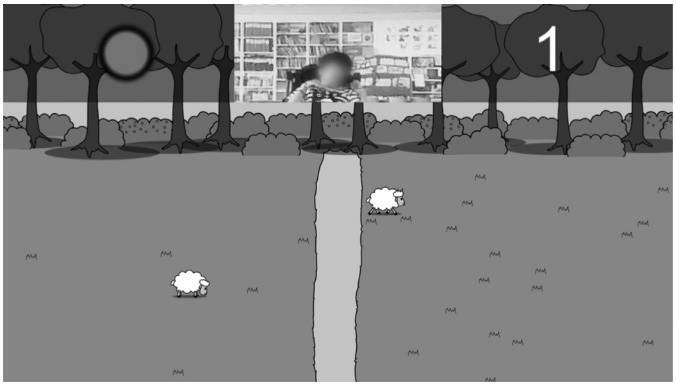

Fig. 2. A screenshot from a level of KiSens Números.

This software is a suite of exercises designed to help teach early ICT (Information and Communication Technology) skills through cause and effect, switch building, timed activation, targeting and row scanning activities. Our interest in SEN Switcher arose because this videogame waits for user events to continue, respecting user timing. KiSens Números has adapted SEN Switchers principles to the typical mechanics of software designed for people with motor disabilities, but using the Kinect sensor as the control method, improving the graphical user interface and adding control elements, such as, for example, a semaphore whose functioning will be explained later on. The game has six levels, each with a different scene and graphics. The goal is to count the number of elements there are on each level. The interface of KiSens Números has a picture of a colorful landscape. At the top of the screen there is a panel showing a semaphore, the image captured by the Kinect camera, and an event counter. The camera focuses on the subjects face and follows head movements right or left. When the semaphore turns green, the user can perform a movement to launch an event. When the event is recognized by KiSens Números an animation is played, a voice says how many events have been counted and the semaphore turns red until the animation ends. If the user performs a movement while the semaphore is red, the system does not launch an event. As a reinforcement, the videogame makes a sound to alert the user when the semaphore turns green and when the level has finished. Fig. 2 shows a screenshot of level 2 of the game. On this level, the user must count the number of sheep grazing on the left of the screen.

2.3. Data collection

As was done in (Calderon et al., 2011), we were able to collect a certain amount of information using the Kinect itself. KiSens Números recorded the original data supplied by Kinect and some relevant data from the session. All user movements were recorded during the execution of the level, regardless of whether the semaphore allowed the user to perform them or not. This information was stored in log files in XML format for each level that the user performed. With these files we will be able to replicate and validate the session results.

3. Experiments

We collaborated with two centers:

- The Specific Special Education Center Directora Mercedes Sanromá. This center is, basically, a school for children with disabilities.
- The Association of Cerebral palsy Centre (ASPACE) of Seville. This center supports adults with CP who have concluded their schooling, but have problems finding a job.

At the school, children have learnt to use technologies but many of them have problems accessing the computer with a keyboard and mouse and generally use some kind of switch (Button, Push Rod, etc) which is usually too inefficient and uncomfortable. However, there are people at the association who can use the computer via a keyboard and a mouse, but most of them cannot access the technology because they have not found an access device suited to their motor characteristics. These centers also have a busy program of planned activities such as rehabilitation, education or cultural activities, which meant that we only had a short period of time to perform our experiments. Due to these limitations, two independent experiments were planned as follows:

Table 1

Characteristics of the participants in Experiment 1.

User ID	Age	Gender	Kinect	Button
1	12	F	Head	Button
2	15	F	Head	Push rod
3	16	F	Head	Push rod
4	15	M	Right hand	Button
5	16	M	Right hand	Push rod
6	11	F	Right hand	Button
7	20	M	Right hand	Button
8	9	M	Head	Button
9	11	F	Right hand	Push rod
10	32	M	Head	Head wand + Button

Experiment 1: This experiment focused on people used to accessing a computer by means of a Switch. The main goal was to gauge the performance of Kinect with users familiarized with a Switch and trace a learning curve. In this case, we assumed that user performances with the switch device should be quite steady. For this reason, in order to get better results tracing the Kinect learning curve, we unbalanced the number of sessions with Kinect. Users completed eight sessions with Kinect and only one with the kind of Switch they normally use.

Experiment 2: The main goal in this experiment was to study the use of Kinect as an access device compared to the Switch in users who had never accessed a computer, either using a Kinect or a Switch. Both interaction modes (Kinect and Switch) were new to them.

The users completed four sessions using Kinect and four sessions using a Switch adapted to their motor capabilities. To avoid learning and tiredness effects we split this group into two subgroups. The subgroup E2A started with Kinect whereas the other subgroup started with the Switch. Participants were randomly assigned to each subgroup.

Fig. 3 shows the timelines for the experiments.

3.1. Participants

Our goal was to study the behavior of Kinect when used as an access device by people with involuntary movements, and for this purpose we wanted to characterize these involuntary movements. However, in practice this task was unworkable because each user with cerebral palsy had a range of different disorders and the casuistry was wide. Some users were so severely affected they could not communicate or perform any movement; while others were only slightly affected and they could access their computer using a keyboard and a mouse.

For this reason we established the following inclusion criteria:

- Over 5 years old.
- Able to perform some head or hand movement.
- Able to understand, learn, and follow simple instructions.
- Voluntary agreement to participate in this study.

And the exclusion criteria were as follows:

- Severe visual disability.
- Regular access to the computer in a conventional way using mouse and keyboard.

The criteria were assessed and enforced by a member of staff from each center with the help of one of our researchers.

Table 1 gives a brief outline of the participants in Experiment 1 and shows the ID, age and gender of the user, the body part used to interact with Kinect and the switch, and the type of switch.

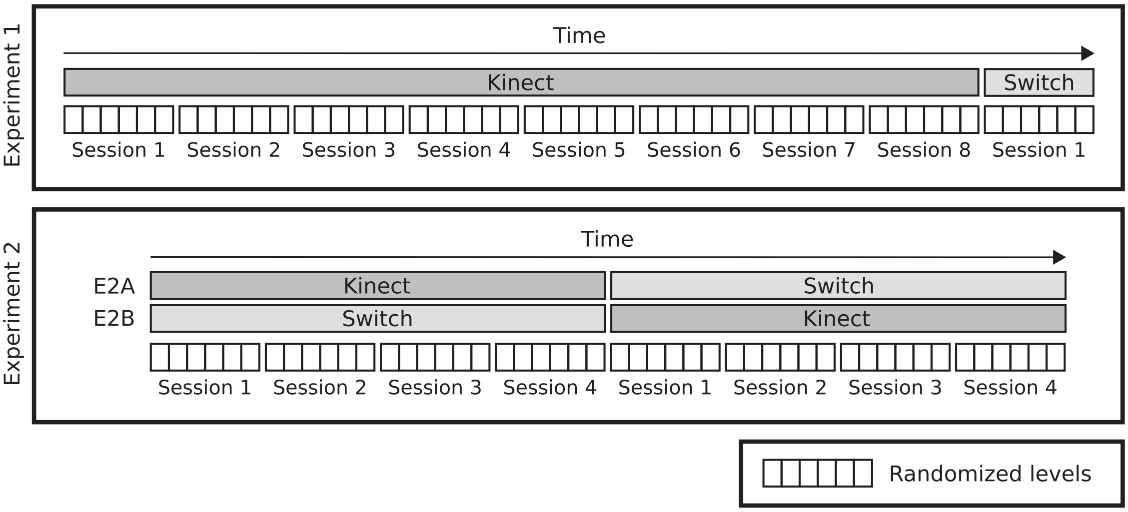

Fig. 3. Timelines for Experiments 1 and 2.

Table 2
Characteristics of the participants in Experiment 2.

User ID	Age	Gender	Kinect	Button
11	42	F	Left hand	Button
12	35	F	Left hand	Button
13	42	M	Right hand	Button
14	40	M	Head	Push rod
15	36	F	Left hand	Push rod
16	23	M	Head	Push rod
17	55	F	Head	Push rod
18	35	M	Right hand	Button

Table 2 gives a brief outline of the participants in Experiment 2 and shows the ID, age and gender of the user, the body part used to interact with Kinect and the switch, and the type of switch.

It is important to note that some limitations were beyond our control. The small number of participants and their age were due to the limited number of subjects in the centers that collaborated in the study. Furthermore, their experience with technology depended on their age and their socio-economic position. Therefore, all users who met the criteria in both centers were recruited to get the greatest number of participants. Participants were grouped according to their experience with the switch, regardless of their age.

3.2. Procedure

KiSens Números includes a special mode for performing experimental sessions. The sessions were identical in Experiments 1 and 2. Each consisted of a set of six levels of the game which automatically executed one after another in a quasi-random way. To overcome a level, users had to perform a number of events that coincided with the number of the level (i.e. level 3 needed three events). Hence, at the end of a session users had to have performed at least twenty-one events. The goal of the test was to record the number of events performed by users. In addition, all levels had the same level of difficulty.

Before the test sessions, all users performed a preliminary session to configure their profile, adjust their control of Kinect and familiarize themselves with the game and the mechanics of the sessions. These control adjustments were conditioned by users' physical limitations and were carried out with the help of a member of staff from the center. The process consisted of choosing the body part to interact with both devices and then adjusting the threshold for Kinect. The users in Experiment 1 used their typical setup; while in Experiment 2, all parts of the body were tested for each user and then the most comfortable part with the best motor control was chosen in each case to avoid fatigue. Each subject used the same body part to interact with Kinect and the Switch.

The threshold was programmed as a value to be configured in the game options menu as a percentage in a similar way to mouse sensitivity: the greater the sensitivity the less the speed of movement required to launch an event and vice versa. The threshold configuration was set after the body part was chosen. The process to set the correct value for each user consisted of adjusting the sensitivity at the game configuration and checking whether the value was sufficient to launch an event according to the user mobility, but trying to choose the minimum value to avoid undesired events. Furthermore, a number of actuation rules were established to control the sessions and avoid adulterated results:

- The sessions were performed in a closed room with only the user, a monitor, and the researchers.
- Sessions could not be interrupted.
- Nobody could pass in front of the Kinect during the sessions.
- All types of distractions were avoided.

Each session was performed in a closed room in which there was one user accompanied by a member of staff from the center and one of our researchers. The tests were approved by the ethics committee of the Universidad de Sevilla and were performed with the consent of the users and their families.

3.3. Measurements

Among the data collected by the game during the test there were three parameters of particular interest because they told us how many errors users had committed:

- Level ID: to identify which level the data refers to. As said, this value is equal to the minimum number of events users must perform to complete it and the number of elements to be counted.
- Total events: indicates how many valid movements users have made during the level.
- Errors: indicates how many extra movements users have performed. This value is the result of subtracting Level ID from Total events.

Apart from the data collected by KiSens Números in the user sessions, we recorded all sessions on video to check whether there had been any abnormal situations when studying the results.

4. Results

For each level, participants had to perform a set of volitional movements to accomplish the task. Errors made during its execution, given as

Table 3
Errors by user and session in Experiment 1.

	Number of errors										
	Kinect									Switch	
	Session								Mean		Δerrors
User ID	1	2	3	4	5	6	7	8		9	
1	26	22	30	16	9	24	23	25	21.88	3	18.88
3	4	3	9	4	12	3	2	5	5.25	3	2.25
4	1	5	12	4	6	10	10	8	7	9	−2
5	7	12	19	11	9	10	10	22	12.5	25	−12.5
6	10	9	4	18	10	8	10	8	9.63	35	−25.37
7	11	0	5	1	1	2	1	5	3.25	7	−3.75
9	4	4	1	12	9	13	8	1	6.5	24	−17.5
10	1	6	4	1	1	0	5	6	3	0	3
Mean	8	7.63	10.5	8.38	7.13	8.75	8.63	10	8.63	13.25	−4.62

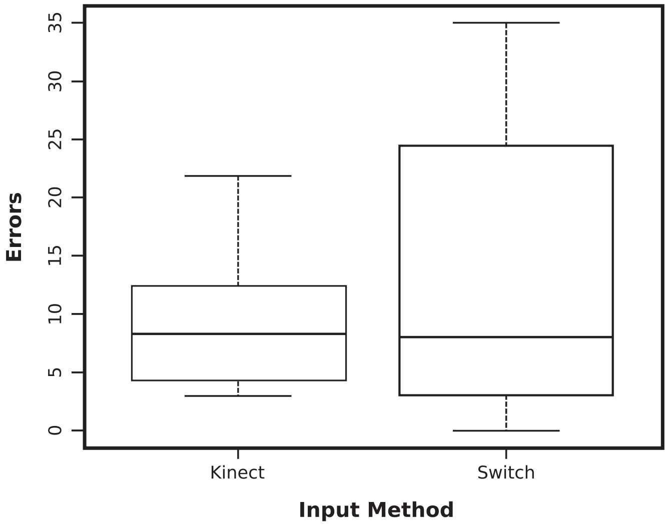

Fig. 4. Boxplot of errors by input access method in Experiment 1.

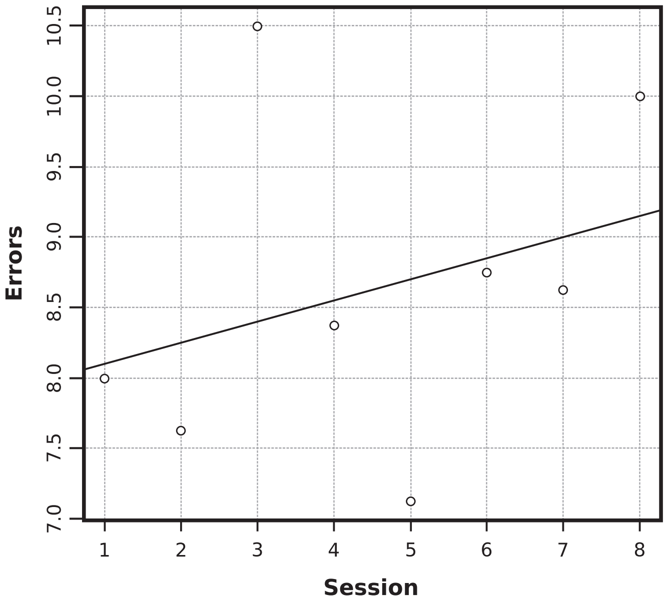

Fig. 5. Learning curve in Experiment 1.

the number of extra movements required to carry out the task, were used as an indicator of performance. The statistical analysis was conducted using RStudio version 0.98.493.

4.1. *Experiment 1*

Table 3 shows the number of errors made per user and session and their means. Users 2 and 8 were excluded from further study because the former did not finish the nine sessions and the latter did not become involved in the experiments, behaving in a distracted manner in each session. For some users the number of errors with a Switch was greater than those made by other users with the same access device or the number they themselves made using Kinect. These errors were made by clicking the Switch more than necessary; in part, this was because they usually find it difficult to get to the Switch and execute the pressing action accurately. Without significant differences between them, users 4 and 7 also made fewer errors with Kinect than with Switch. The remaining users, 1, 3 and 10, made fewer errors with the Switch interaction method. User 1 made more errors than the other users, he roughly doubled the number of movements needed in the experiment (21 per session or 168 overall). The last row in Table 3 shows the mean values of error per session for all users. This shows that the tendency of the errors as the days went by was to increase slightly.

The Δ errors variable shows the difference between the means of errors with Kinect and Switch.

Fig. 4 shows the boxplot of errors using the input access method. The mean number of Kinect errors 8.63 ± 2.20 (means ± standard error) was lower than those made using the traditional method, Switch (13.25 ± 4.57). The mean value of Δerrors (Δerrors = −4.625) suggests that the number of errors committed using Kinect was lower than when using the Switch, although this was non-significant. Δerrors had a normal distribution (shapiro-wilk p = 0.94) and the Student *t*-test (p = 0.37) determined that there was no significant difference between Kinect and Switch.

Fig. 5 depicts the results of the errors versus sessions plot with a line whose parameters were estimated by linear regression. The fit was quite poor, the R^2 value was 0.10, the *t*-test for slope of the line gave a *p*-value equal to 0.83, which meant that a slope different to zero was non-significant.

4.2. *Experiment 2*

Users in this group, who had never used any accessing device before, performed four sessions using Kinect, and four additional ones using a Switch. User 12 was excluded because he did not become involved in the experiments and behaved in a distracted manner in each session. Table 4 shows the results and Fig. 6 the equivalent boxplot. According to the number of errors they produced, Users 11, 14 and 15 showed better results with Kinect as the input device than with the Switch. In general, the average number of errors using Kinect was 8.57 ± 1.4 whereas with Switch it was 7.89 ± 1.64, which makes Δerrors = 0.68.

Table 4
Errors by user and session in Experiment 2.

	Number of errors										
	Kinect sessions				Switch sessions				Means		Δerrors
User ID	1	2	3	4	5	6	7	8	Kinect	Switch	
11	0	3	0	0	2	3	5	1	0.75	2.75	−2
13	5	6	4	8	1	0	0	1	5.75	0.5	5.25
14	8	8	10	10	20	19	9	14	9	15.5	−6.5
15	4	9	7	3	30	16	17	30	5.75	23.25	−17.5
16	12	37	2	4	6	3	11	9	13.75	7.25	6.5
17	15	11	23	9	2	5	7	5	14.5	4.75	9.75
18	10	10	12	10	1	1	2	1	10.5	1.25	9.25
Mean	7.71	12	8.28	6.28	8.85	6.71	7.28	8.71	8.57	7.89	0.68

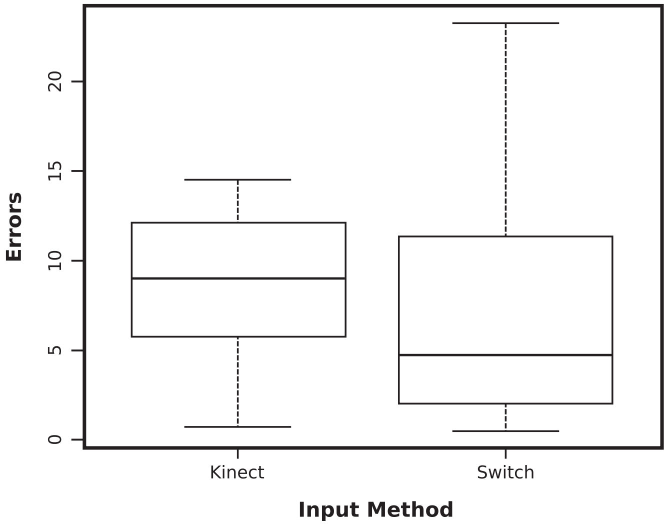

Fig. 6. Boxplot of errors according to input access method in Experiment 2.

The variable had a normal distribution (Shapiro-Wilk p = 0.22) and, moreover, there was no significant difference between both devices (Student *t*-test p = 0.86).

5. Discussion

As we stated in the results section, there were no significant differences between Kinect and Switch. However, we need to find out more about certain cases in which a large number of errors were made with a concrete device: users 1, 5, 6, 9 and 15. We must study these particular cases to gain a better understanding of the data, discard possible outliers caused by system errors and obtain information about the behavior of Kinect and Switch.

User 1 (Means of error: Kinect = 21.88 and Switch = 3) performed the sessions with Kinect using head movements. This user had bad postural control of her head and produced many involuntary movements that were difficult to distinguish from voluntary ones. To use a Switch, she only had to lean her head toward the device momentarily and immediately separate it, generating fewer errors than with Kinect which continuously captured movements. As a result, Kinect detected many more involuntary movements than the Switch, making the latter more effective. For users within this profile, who cannot perform voluntary movements faster than involuntary ones, a motion-capture based system is unlikely to be efficient. Despite that, this user expressed her preference for Kinect over the Switch, underlining the motivational aspect of this device.

User 6 (Means of error: Kinect = 9.63 and Switch = 35) used his right hand to press the Switch and tended to support it over the Switch. This meant the Switch was affected by the users spastic movements which produced an increasing number of errors in the results. In this case, Kinect was less sensitive to this kind of problem. Something similar occurred with user 9 (Means of error: Kinect = 8.5 and Switch = 24).

To complete the sessions she used her right hand to press a Switch. Her spastic movements were captured, therefore increasing the number of errors committed with the Switch. In this case as well, Kinect was unaffected by this situation.

User 5 showed interest in completing the levels. Since the videogame does not penalise excess events, the user continued performing movements to complete the level as soon as possible without paying attention to the semaphore. This should have affected both devices equally, but as we have just pointed out, Kinect is less sensitive to certain movements which may explain the error differences between devices.

User 15 (Means of error: Kinect = 5.75 and Switch = 23.25) was affected by an important amount of large-amplitude spastic movements; however, she was capable of performing voluntary movements that could be distinguished from the rest. This allowed her to use Kinect properly; in contrast, she had to make a great effort to use the Switch.

Although the rest of the users also showed involuntary movements and a lack of motor control, their cases were much less severe. Taking this into account, we can establish that there is a correlation between users mobility and the number of errors obtained.

5.1. *Experiment comparisons at descriptive level*

In this section, we conduct a cross sectional study to get an overview of the results for each device in both experiments. On the one hand, Kinect showed similar results (8.63 and 8.57 in Experiments 1 and 2 respectively) and it had never been used by any of the participants. On the other hand, Switch showed a much higher mean of errors (13.25 and 7.89 in Experiments 1 and 2 respectively). This fact is noteworthy if we take into account that the participants in Experiment 1 had experience of using the Switch and the participants in Experiment 2 had never used it. A possible reason for this is that in Experiment 2 there was only one user with a lot of errors (User 15) whereas in Experiment 1 there were three (5, 6 and 9), which makes the mean increase significantly. In addition, the participants in Experiment 2 were adults whereas the users in Experiment 1 were children, this fact may imply differences in the level of control over their movements since, due to their age, they have received less physiotherapy and, as mentioned, the switch is more sensitive to certain types of involuntary movements.

5.2. *Observations*

Thanks to the caregivers and the time we spent with the users during the sessions, we were able to gather information about their experiences with Kinect that we think is interesting. In our visits to both centers we saw that users always wanted to participate in the tests. In addition, after the last session they were all asked about their experience with Kinect. As communication with the users was difficult, the caregivers helped us to interpret their responses. All the participants answered that they had enjoyed playing with Kinect and would like to take part in future tests with this technology. Taking into account that they were not paid to participate in tests, we think that such a response was very positive and shows the motivating effect of Kinect. Furthermore, on several occasions user 14 manifested to his caregiver that he wanted to have a Kinect and a copy of KiSenS at home to play when he wanted. We found the case of user 15 particularly striking, her caregiver thought that she could not use a computer because her motor impairments always prevented her from using conventional devices or a switch, but the results showed that with the appropriate device she could do it.

On the other hand, there were other cases that should be taken into account in future works. As we saw, users 8 and 12 showed a lack of attention which is associated to cerebral palsy and makes it difficult for them to finish tasks. Likewise, user 13 showed mood swings also associated to cerebral palsy. At times he would be angry and refuse to participate in any activity, and then fortunately some time later his mood would change again and he would perform his session. We understand that these conditions associated to cerebral palsy are beyond our control; however, introducing another kind of stimuli into the game, or changing the way sessions are planned, might be able to mitigate these effects.

6. Conclusions and future work

The main goal of this study was to assess the behavior of Kinect as an access device for people with CP and its performance in people with involuntary movements. Despite the low number of subjects available to perform tests, this study shows that Kinect can be useful as an access device for some users, particularly when they show involuntary movements. These results could improve with better algorithms. In addition, results reveal that in these cases the switch is not appropriate because it is affected by these involuntary movements. In the same way, there are some cases in which the use of Kinect is not recommendable because of users bad postural control. Furthermore, the results lead us to think that is possible to design a software to determine the mobility of people with CP. This information could be used for classification purposes, but also to determine the most efficient access device for users.

The casuistry of CP is varied and each user needs a specific period of time to react and control his/her movements. Indeed, these factors may vary for the same individual at different times. For that reason, the game used in this work was designed to respect user timing and the collection of time data was discarded. However, in the light of the results we think that time data may provide valuable information about user mobility and in future works it will be taken into account.

According to other studies, in this work we assumed that Kinect was sufficiently accurate. Although our study goals did not include confirming this assumption, the results showed that Kinect performance was similar to Switch in most cases and there also seemed to be a correspondence between user motor characteristics and number of errors, suggesting effectively that Kinect is quite accurate. In future works we will use Kinect v2 to improve precision but the possibility of false positives (e.g. the algorithm launches an event but the user has not performed a movement quickly enough) will be considered to confirm that special cases are not outliers produced by system errors.

This work is a preliminary study that has helped us get valuable data about the behavior of Kinect when used by people with CP as an access device. The results have encouraged us to develop a software to capture more accurate data to study users' movements. This information will enable us to design a better algorithm to use Kinect as an access device but will also help us confirm the possibilities and limitations of Kinect as an assistive technology.

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