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Short communication

Suitability of functional evaluation embedded in serious game rehabilitation exercises to assess motor development across lifespan

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ABSTRACT

The aim of this study was to determine if the results of activities performed using specially developed serious games for physical rehabilitation could be used as an indicator of the natural maturation and decline of motor control in healthy participants. Eighty-one participants (19 children (5–15 years old), 40 adults (18–65 years old) and 22 aged subjects (60–88 years old) participated in this study. Motions performed were recorded using the Kinect sensor. Three different exercises embedded in the games were used to assess upper limb, trunk and lower limb control. The trial duration and accuracy, measures of gross motor function and fine motor control, respectively, were computed for each participant. ANOVA tests shows statistically significant differences between the three groups for duration (53 ± 15, 27 ± 10 and 119 ± 30 s for children, adults and elderly subjects respectively) and accuracy (87 ± 5, 89 ± 10 and 70 ± 8% for children, adults and elderly subjects respectively). The slopes of the curves that approximated the evolution of the performance over various ages are coherent with previous studies about motor control development and physiological decline. The proposed solution, i.e. serious games rehabilitation exercises coupled to motion analysis, seems to be an interesting tool to assess global motor function. Further studies are needed to study the influence of pathologies on the studied parameters.

1. Introduction

The integration of video games in physical rehabilitation is becoming increasingly popular [1]. Two different approaches are possible, either using existing commercial video games (i.e., not specifically developed for therapeutic aims) or specifically developed solutions, called Serious Games (SG) [2], for rehabilitation. The second option is based on specific clinical needs and is therefore, in theory, more suited for patients. Another advantage of the SG is that the motions performed by the patients can be recorded and analyzed thanks to the integration of scientifically validated methods for functional validation with the SG software [3].

Gross and fine motor controls are complex tasks involving many different components of the central and peripheral nervous system [4]. Important natural alterations occur during lifetime: a slow maturation of all the components during childhood to acquire gross and later fine motor control [5]; then physiological declines of motor functions are observed starting around 60 years old [6].

The main aim of this paper was to determine if it is possible to observe differences across age groups in motor control by analyzing the motion performed by the subjects when they are performing rehabilitation exercises using a specially-dedicated SG. A second aim was to assess the use of functional evaluation associated to cost-effective hardware to objectively quantify clinically-relevant parameters such as speed and accuracy [7].

2. Materials and methods

Eighty-one participants (19 children from 5 to 15 years old, 10 ± 3 years old, 40 adults from 18 to 65 years old, 37 ± 14 years old

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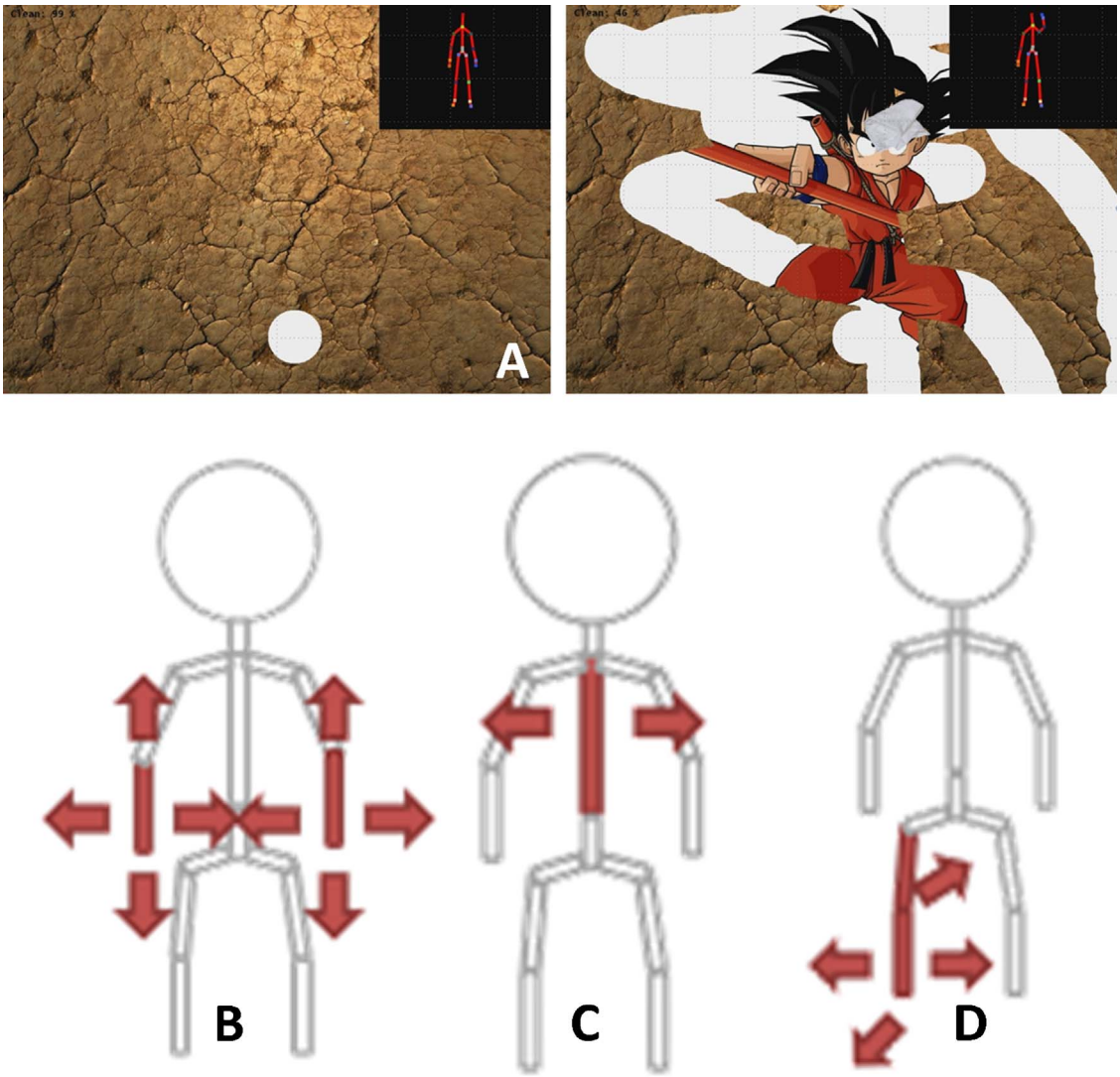

Fig. 1. A screenshots of the games. B games controlled with the upper limbs (main joint displacements were shoulder flexion and shoulder abduction). C games controlled with the trunk (trunk flexion-extension and lateral bending). D games controlled with the lower limb (mainly hip flexion-extension and hip abduction/adduction).

and 22 aged subjects from 60 to 88 years old, 74 ± 6 years old) participated in this study. This study was approved by the Ethical Committee of the Erasme Hospital (EudraCT/CCB: B406201525316, B406201318257 and B406201526116 for children, adults and aged subjects respectively) and written informed consent was obtained from all subjects or their legal representatives prior to their participation. Exclusion criteria were neurological conditions, balance deficits or orthopedic disorders in the last six months.

A specific SG has been developed (Fig. 1). This study is part of a much larger project aiming to develop rehabilitation exercises embedded in SGs. These games were carefully designed, in collaboration with clinicians from various rehabilitation centers, to include physical therapy exercises enabling therapists to train patients along a variety of schemes such as joint control, stretching, balance and posture control. The aim of the SG selected for this study was to clean a screen covered by virtual mud using a cloth controlled with hands, trunk or legs alternatively (the aged subjects did not play the entire game for safety reasons). The motion of the players was recorded by a Kinect sensor [3]. Motions data were stored in standard format (i.e., C3D) for further analysis. Participants were invited to stand in front of the screen and the sensor. Three repetitions of each SG modality were played. The mean of the three repetitions was used for statistical analysis.

Two parameters were computed from the SG output: the time required to clean 90% of the screen was recorded as an indicator of the global performance (i.e., gross motor control analysis). The accuracy of the motion was also assessed by computing the number of times that the subject is placing the cloth in the same position on the screen. The number of frames where the cloth was in a position that had already been cleaned were computed ("cleaned" frames). The result was finally expressed in percentage ($\text{accuracy} = 100 - ((\frac{\text{Numberof}\langle\text{errorimage}\rangle\#\text{XPS}\#\text{ldquo;}\langle/\text{errorimage}\rangle\text{cleaned"frames}}{\text{Totalnumberoffframes}}) \times 100)$). The higher the accuracy score, the better the results in term of performance.

Normality of each parameter for each group was checked using the Shapiro-Wilk tests. ANOVA tests were applied to compare the three groups. Bonferroni tests were used to correct for multiple comparisons in our post-hoc analysis.

In agreement with previous studies of the development of motor control[5] and physiological decline[6], several functions were fitted to our data.

3. Results

All variables studied are normally distributed ($p > 0.05$) and hence parametric testing was used.

Results and statistics are presented in Table 1. ANOVA tests shows