



## Wearable-based electronics to objectively support diagnosis of motor impairments in school-aged children

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### ABSTRACT

Developmental coordination disorder (DCD) and attention-deficit hyperactivity disorder (ADHD) are neuro-developmental disorders, starting in childhood, which can affect the planning of movements and the coordination.

We investigated how and in which measure a system based on wearable inertial measurement units (IMUs) can provide an objective support to the diagnosis of motor impairments in school-aged children.

The IMUs measured linear and rotational movements of 37 schoolchildren, 7–10yo, 17 patients and 20 control subjects, during the execution of motor exercises, performed under medical and psychiatric supervision, to assess different aspects of the motor coordination.

The measured motor parameters showed a high degree of significance in discriminating the ADHD/DCD patients from the healthy subjects, pointing out which motor tasks are worth focusing on. So, medical doctors have a novel key lecture to state a diagnosis, gaining in objectivity with respect to the standard procedures which mainly involve subjective human judgment.

Differently to other works, we propose a novel approach in terms of number of used IMUs and of performed motor tasks. Moreover, we demonstrate the meaningful parameters to be considered as more discriminant in supporting the medical diagnosis.

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### 1. Introduction

The human motor control is the way the neuromuscular system activates/coordinates muscles/limbs to perform motor skills. For some school-aged children, this control does not refine over time as it is expected to do, so are diagnosed with developmental coordination disorder (DCD) and/or attention-deficit hyperactivity disorder (ADHD).

Children with DCD act with poor coordination, poor postural control and/or fine or gross motor clumsiness, without achieving age-appropriate activities of daily living, such as walking, playing catch, etc. (Smits-engelsman, 2011).

Children with ADHD can be predominantly hyperactive or inattentive or a combined type (American Psychiatric Association, 2013). The hyperactivity results in inability to control impulses, leading to squirm, fidget, or bounce when sitting. Studies investigating ADHD referred impaired motor skills in terms of poor coordination and poor gross and fine motor functioning (Bart et al., 2010).

DCD results 6% in prevalence worldwide (Smits-engelsman, 2011); ADHD is different among countries, but averages 5% in prevalence (Sayal et al., 2017).

Interestingly, DCD and ADHD are frequently combined, their comorbidity as high as 50% (Buderath et al., 2009; Gouardins et al., 2015; Kaiser et al., 2015), their relationship remaining pretty unknown (Sergeant et al., 2006). Moreover, both disorders have been linked to psychological problems, reduced academic performance, and reading and spelling difficulties, thus the idea of a single etiology has been suggested (Dewey and Bernier, 2016; Kaplan et al., 1998).

According to the *diagnostic and statistical manual of mental disorders* (DSM-5TM, 5th edition) (American Psychiatric Association, 2013) and the *international classification of mental and behavioral disorders* (ICD-10, 10th revision) (World Health Organization, 1992), the diagnosis of motor difficulties in children can be made by examining the medical history, by filling questionnaires for parents/teachers, and by motor tests. However, different authors have

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