Dynamics of Learning: Behaviour and Lived Experiences. The role of exploratory strategies

I. Context, positioning and objective(s) of the proposal

Studies of motor learning are numerous. However, most have assessed learning by comparing specific task behaviours before and after a learning intervention [1]. Such comparisons do not help us understand the *processes* involved during the learning period [2]. For example, recent studies have shown that learning dynamics can exhibit an 'intermittent regime', i.e. a phenomenon of alternation between a newly acquired behaviour and temporary returns to previous behaviours [3,4]. Previous behaviours are used as a "bridgehead" to explore new behavioural opportunities. Teachers, ergonomists and architects can encourage individuals in sport, professional and everyday life contexts to explore new behaviours through careful design of the environment [5]. The environment needs to be structured so individuals can act in specific, intended ways without being explicitly told about what to do or how to do it (for example a ladder invites climbing it, however a fire-fighter can climb by grasping either the rungs or rails of the ladder). This type of learning is based on the idea that individuals learn by adapting continuously to an environment through more effective exploration of opportunities of action offered by that environment. Although studies focusing on exploratory strategies during learning have been undertaken in the past [6-8], there have never been experimental tests that have manipulated learning design. Three recent studies (from PhD dissertations) investigating exploratory activities in motor learning have shown that the degree of complexity and constraint influences the duration of the intermittent period where both old and new movements are used [9-11]. For individuals to explore their environment, to determine what movements are feasible, they likely use their vision. However, no studies have investigated whether exploratory strategies for picking up information through vision are related to previewing the environment in which an individual is going to move. Also, there has been no work investigating what an individual is going to explore during his/her course of action. Although the scientific literature relating to visual search strategies is abundant for performance and learning of interceptive actions (e.g., in tennis or football), it is rare: 1) regarding the role of vision to guide complex multi-joint locomotion (e.g. when climbing [12-14]), and 2), when locomotion is analysed in an ecological performance context. This dual objective is the **first original idea of this project in the humanities: Modelling the dynamics of learning through analysis of visual-motor exploration strategies in a climbing task according to the degree of novelty of the performance situations encountered.** We will test the hypothesis that the duration of the intermittent regime is associated with the ability to pick up opportunities of actions offered by the environment [15]. Doing this project in an ecological performance context raises a scientific challenge for computational and data sciences, going beyond the climbing task; **distinguishing head movements from eye movements to locate participant visual fixations on the global observed scene** (not on the local scene viewed at a given time by the individual). **The main aim of this project for the computational and data sciences, in terms of signal and image processing, will be to identify visual fixations in the global scene**.

Although studies on learning have provided findings about behavioural changes, it was recently emphasised that investigating how these behavioural changes are experienced may be important to understand how an individual constructs meaning about an activity [16,17]. We hypothesise that the way each individual experiences his/her action is only a small part of the perception of subsequent capabilities and action opportunities (concept of coupling action / perception [15]). Based on these ideas, a **second aim of this humanities project is to model the phenomenology (the experience) of the dynamics of learning as the novelty of the situations encountered is imposed or chosen by each participant. In the computational and data sciences, a key scientific challenge is to achieve an integrative approach to recording behaviour (vision and motor skills), allied to phenomenological data to determine for each individual the extent of an initial repertoire, which is explored during learning (by assessing the duration of the intermittent regime) and then stabilized at the end of learning. The second aim of this project in computational and data sciences is to use cluster analysis (referring to unsupervised machine learning techniques),** designed to group individuals together based on their degree of similarity, without having any *a priori* expectations on the number of groups and the features of these groups. Here the scientific challenge is to take into account the temporal dimensions of learning, behavioural and phenomenological characteristics and uniqueness of each individual.

A learning protocol in a climbing task will be divided into 4 work packages (WP) proposed for fire-fighters. The choice of this population to study is doubly justified: fire-fighters must face situations which are both unique and familiar (a fire in a home has features common to home fires with a uniqueness of the architectural features of the house). Training in this type of intervention is a social issue for the effectiveness of interventions and the protection of fire-fighters.

WP1: *Protocol and Data Collection*: Involves collection of phenomenological, visual and motor data. 3 groups will be tested: a control group where individuals repeat the same climbing route; a group where individuals choose the novelty frequency to change the climbing routes; and a group where the novelty frequency to change the climbing routes is imposed by the experimenter. Each fire-fighter will perform 10 sessions of 1 hour for 5 weeks, followed by a test of transfer and retention one month after the end of the learning intervention. The protocol will be carried out at the climbing gym of the Rouen University campus because of privileged access.

WP2: *Analysis of visual-motor exploration*: Body markers filmed by a multi-camera system will continuously record the position of fire-fighters on the climbing route and distinguish exploratory actions (i.e. limb movements not associated to hip movement) relative to performatory actions (i.e., limb movements associated to hip movement). We have already used this methodology successfully in the PhD of D. Orth [10]. Visual data will be collected with an eye tracker system. To overcome the time-consuming traditional qualitative analyses, we will aim to automatically identify visual fixations in the global scene using two methods: 1) Locate the position and orientation of the head from the head markers to locate the local scene (and the visual fixations in this scene) with respect to the global scene, using techniques of "tracking"; 2) Rebuilding the global scene from the agglomeration of local scenes, using techniques of "mapping" (SLAM: *Simultaneous Localization And Mapping*). Finally, by connecting visual and hip movement data, we can distinguish exploratory (i.e. visual fixations not associated to hip movement) and performatory (i.e. visual fixations associated to hip movement) visual search behaviours.

WP3: *Analysis of the experience*: records of activity traces (audio, video and picture) in each session will be presented to the fire-fighters immediately after the session to carry out self-confrontation interviews according to the methodology course-of-action [16,17], to identify typical activity patterns during learning.

WP4: *Analysis of the dynamics of learning*: Learning can be divided into three phases: 1) initial stable behaviour, 2) intermittent regime of transient behaviour, 3) final stable behaviour. The goal is to automatically segment and characterise these phases. The challenge resides in: 1) the joint task of segmentation and clustering, 2) modelling of the dynamics that will integrate visual, motor and phenomenological data (as previously done by Seifert [17] and Bourbousson [16] in another field other than learning), and 3) the spatial dimensions (variance of envelope covered by the four limbs, visual fixations path and hip path can be analysed by Weighted Current technique [18]) and temporal (sequences of actions and visual fixations, as well as typical activity patterns can be analysed by Markovian modelling and clustering).

II. Organisation of the project and resources

L. Seifert [Involvement: 30%] (First rank at advanced certificate of Physical Education 1999, PhD 2003, Lecturer 2004, A/Prof. 2011, Full Prof. 2016), deputy director of CETAPS lab. (University of Rouen Normandy). Leader of Young Researcher national grant (*DynaMov*) funded by National Agency of Research (ANR) between 2013-2017, which led to 13 international publications, the co-edition of a collective book (www.routledge.com/9781138927582) and the development of algorithms in open access on the e-lab *Ecological Dynamics & Sport Performance* (http://eecod2014.wix.com/e-ecod) which is an international platform for exchange of resources that I lead with K. Davids, which is part of the UniTwin program supported by UNESCO (http://unitwin-cs.org). Author of 90 international publications and co-editor of two books. Holder of Outstanding Science Award (2010-2018). Holder of 10 research contracts (Normandy Region, National and European) for 1.35M€ since 2008. Supervisor of 7 PhD theses between 2008 and 2015.

The current consortium consists of 3 areas of expertise: 1) *Behaviour*: **J. Komar** [Involvement: 25%] Lecturer, CETAPS lab., University of Rouen Normandy; **R. Thouvarecq** [Involvement: 20%] Prof., CETAPS lab., University of Rouen Normandy; **K. Davids** [Involvement: 15%] Prof., Sheffield Hallam University, UK; **C. Button** [Involvement: 15%] A/Prof., University of Otago, NZ; **J. Croft** [Involvement: 20%] Lecturer, Edith Cowan University, Australia. 2) *Computational and data sciences*: **R. Hérault** [Involvement: 20%] Lecturer, LITIS lab., INSA of Rouen Normandy, **G. Gasso** [Involvement: 20%] Prof., LITIS lab., INSA of Rouen Normandy; **P. Vasseur** [Involvement: 15%] Prof., LITIS lab., University of

Rouen Normandy. 3) *Phenomenology*: **D. Ade** [Involvement: 20%] Lecturer, CETAPS lab., University of Rouen Normandy; **J. Bourbousson** [Involvement: 20%] A/Prof., MIP lab., Nantes University; **D. Hauw** [Involvement: 15%] Prof., ISSUL, University of Lausanne, Switzerland.

The consortium offers a number of guarantees for its implementation: 1) It builds on the success of the Young Researcher *DynaMov* national grant since 4 members (underlined) are again involved. 2) It articulates humanities and computational and data sciences as the key representative labs CETAPS and LITIS both based in Rouen with strong historical relationships (e.g. Hérault and Seifert share 21 publications and presentations in international conferences since 2010). 3) Each centre of expertise brings together international scientists who are used to work together and share similar or compatible approaches and/or methodologies. 4 examples of publication can attest this strong existing collaboration: **Seifert** L., **Komar J.**, Araujo D., **Davids** K. (2016). Neurobiological degeneracy: A key property for functional adaptations of perception and actions to constraints. Neurosci Biobehav Reviews. 69, 159-165. **IF: 8.58. Seifert** L., Wattebled L., **Herault** R., Poizat G., **Ade** D., Gal-Petitfaux N., **Davids** K. (2014). Neurobiological degeneracy and functional affordance perception carrier intra-individual variability of inter-limb coordination during ice climbing. PLoS ONE 9 (2): e89865. **IF: 3.73. Seifert** L., Wattebled L., L'hermette M., Bideault G., **Hérault** R., **Davids** K. (2013). Skill transfer, affordances and dexterity in different environments climbing. Hum Move Sci. 32, 1339-1352. **IF: 2.1**. **Seifert** L., **Button** C., **Davids** K. (2013) Key properties of expert systems movement in sport: An Ecological Dynamics perspective. Sports Med, 43, 167-178. **IF: 5.2**. The funding requested is 232.2K€ (including 8% of management fees) divided into 3 expenditure items: 1) *Equipment*: 40K€ + for an eye-tracker system + software; 6 video camera. 2) *Temporary staff*: PhD scholarship for Data Mining and Machine Learning of WP4 (94K€). 3) *Direct costs:* 60K€ missions, 21K€ consumables and services.

III. Impact and benefits of the project

The project is in line with the programme *Axis: Numeric Revolution*, associated with *Challenges 7 and 8 of the Action Plan 2017* of the National Agency of Research (ANR). It addresses the research questions that can benefit from the joint contribution of research in the humanities and computational and data sciences to contribute to understanding of the *Theme: Education and Training* by focusing on *modelling of learning*. Our project will contribute to the 32rd Orientation of the National Strategy of Research entitled '*Availability of data and knowledge extraction*': It is stated that research should focus on *how to extract knowledge of non-hierarchical information flow*. Our project is fully in this direction because it will extract knowledge from various and non-hierarchical data such as numerous and long time series 1) Location of limbs, 2) Visual fixations, 2) Typical modes of engagement and concerns. The *scientific impact* will be on 3 levels: 1) Understanding the phase of "intermittent regimes" in learning depending on the degree of novelty of lived situations (through segmentation-classification techniques for the modelling of learning). 2) Understanding the role of visual information in relation to complex activities like climbing actions (using the techniques of SLAM) in exploratory strategies. 3) Understanding the relationship between individual engagement and visual-motor behaviours when exploring new situations, because we assume that these parameters affect the duration of the intermittent regime. Thus, our project contributes to the National Strategy of Research as it aims to meet *scientific challenges, technology and society while pursuing the fundamental research questions in cognitive science about learning*. The *socio-cultural impact* comes in the form of education and training of fire-fighters as well as to understanding of the security of citizens and fire-fighters themselves. This social impact extends to sport science students and more broadly to individuals whose locomotion occurs on a vertical plane, in uncertain situations, in sports fields (e.g., climbing, parkour, free running, skiing) and emergency service workers (e.g., situations of emergency, evacuation and defence by military; workers at height). To this impact, the articulation of phenomenological data with visual-motor exploratory strategies during climbing route previewing and ensuing courses of action will help to understand what is expected with what is experienced during the climb, according to the degree of contextual novelty. This project will provide education for understanding of risk as well as training for emergency strategies by taking advantage of: 1) lived experiences to understand 'engagement *vs.* preservation', 2) visual search strategies, 3) adaptive motor strategies for remaining efficient and secure during performance of complex tasks. The *economic impact* is filing a patent for optimizing the usability range of eye-tracker system.

The *strategy of dissemination and publication* is based on four aspects: 1) To provide open access to the library of Machine Learning developed on the MLOSS platform and open access data base on the site of the e-lab *Ecological Dynamics & Sports Performance*. 2) Publication: 20 publications and international conference papers, organization of a workshop. 3) Filing a patent on the automatic tracking of visual fixations in ecological context of performance (WP2). 4) To provide a training protocol to help education of fire-fighters.