

A new experimental setup to study the structure of curiosity-driven exploration in humans

Brice Miard, Pierre Rouanet, Jonathan Grizou, Pierre-Yves Oudeyer
Flowers Team: Inria, Ensta Paris-Tech
firstname.lastname@inria.fr

I. INTRODUCTION

Curiosity is a key element of human development, driving us to explore spontaneously novel objects, activities and environments [1]. Curiosity-driven exploration strategies permit us to interact, learn and evolve quickly in an open ended world. It is thus an important challenge to understand the fundamental mechanisms of spontaneous exploration and curiosity in humans.

One of the first experiments on this topic was made by Harlow, where monkeys played with simple 2D puzzles to highlight the relation between complexity, motivation and learning [2]. Another early example is McReynolds et al. who created the "curiosity box" where identical boxes, with different toys inside, are presented to young children [3]. Recently, an experiment was made with infants to study action selection guided by intrinsic motivations with a mechatronic board. In this study, subjects have to learn the relation between actions on pushbuttons and the opening of boxes [4]. They showed significant differences in exploration strategy (sensorimotor vs a more learning directed exploration) between three and four years old infants. Despite a number of other psychology and neuroscience experiments in humans and monkeys, we still know little about the precise mechanisms of curiosity [1].

In the last decade, many computational models of curiosity, a form of what has been called intrinsic motivation, have been elaborated [5], [1]. Some of these models specifically targeted the modeling of curiosity and its role in human sensorimotor and cognitive development, showing how it can generate automatically behavioral and cognitive developmental structures sharing interesting similarities with infant development [6], [7]. These lines of work allowed to identify the wide diversity of potential mechanisms that could be at play to drive spontaneous exploration [8]. This also allowed to formulate novel hypotheses, such as the hypothesis that curiosity-driven sensorimotor exploration could be organized as to maximize learning progress [9], [10], which is different from more classical hypothesis conceptualizing curiosity as a drive to maximize uncertainty of novelty. Yet, experimental setups designed so far in the litterature do not allow to separate between these hypotheses. A major research challenge is thus to design experimental setups which could allow to confirm or invalidate individual hypotheses.

Here, we make a step in this direction by presenting an exploratory study with humans designed to analyze and measure properties of curiosity-driven exploration of a priori unknown sensorimotor spaces. More specifically, we are interested in the relation between exploration and learning progress.

II. EXPERIMENTAL SETUP

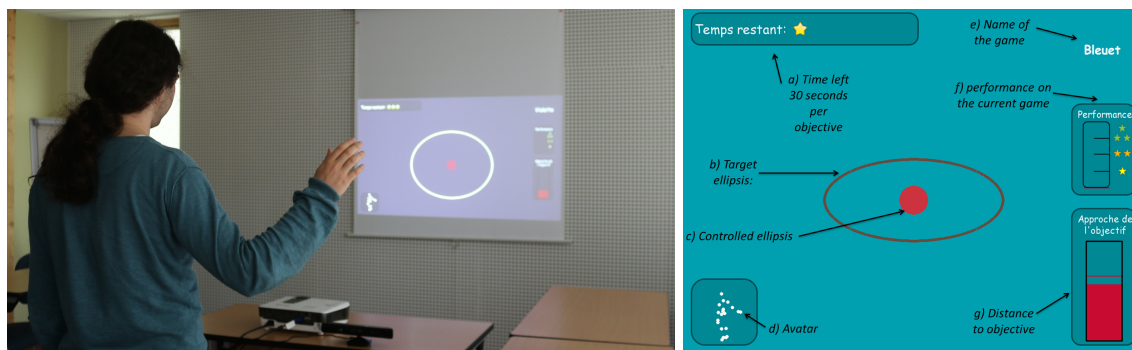


Fig. 1. a) Subjects are exploring how to control an ellipsis displayed on the screen in front of them by moving their body joints tracked by a Kinect device. b) Details of the interface shown to the user on a screen in front of them: in particular, you can see the controlled ellipsis (in red) and the target one (in brown).

This experimental setup is designed as a game setting human subjects into an intrinsically motivated activity [11]. Participants can freely explore and shift between several games, each being about finding a mapping between their movements (body joints tracked by a kinect) and a 2D shape displayed on a screen (an ellipsis). We will first describe the setup in the next section, then present the ongoing users study and preliminary results. In each game, they have to match the shape they control with

randomly generated goals (see figure 1b). When reached, i.e. when the controlled shape is maintained close enough of the target for one second, a new goal is automatically generated. Objectives change every 30 seconds when not reached. Additional performance indicators were added on the screen interface in order to improve subject's intrinsic motivation, implication and comprehension (see figure 1b) [11].

Each of the four games, while visually similar, differ by the difficulty of the underlying mapping (more or less easy to learn). Typically, for each of this mapping, the axes of the ellipsis are controlled by one of the body joint: e.g. the major axis will be controlled by the pitch angle of the left shoulder while the minor axis will be controlled by the yaw angle of the right elbow. Note that in one of the game, a single joint is used to control both axis making the ellipsis a circle. Users are entirely free of changing from one game to another one, thanks to a tablet, when and how often they want. Thus, we can study how, when intrinsically motivated, they divide their time among those four similar games and when and why they changed.

The following protocol was used for the ongoing user's study, so far about twenty participants played our game. First, participants had to fill a questionnaire (on a five Likert scale) aiming at highlighting personality and skill profiles (e.g. practice of body expression activities such as dance or theatre). This pre-questionnaire also include the CEI2 questionnaire [12], a psychological test designed to evaluate level of curiosity. Then, they could play the four different games for a total of 15 minutes. After, they had to do a quick test, play each game for one minute and reach the highest score as possible. Finally, they had to fill another questionnaire to collect their subjective point of view of their user's experience (difficulty, time repartition, progress, expected progress).

During all the experiments, we also record each time they reached a goal and each time they changed games. We can thus compute their learning progression by summing the number of objectives succeeded in a time window. We also recorded the movement of their 20 articulations of their bodies in 3D at 10Hz allowing the study of exploration strategy such as the freezing/unfreezing of degrees of freedom. A video presenting the setup and the experiments is available here: <https://vimeo.com/95383753>.

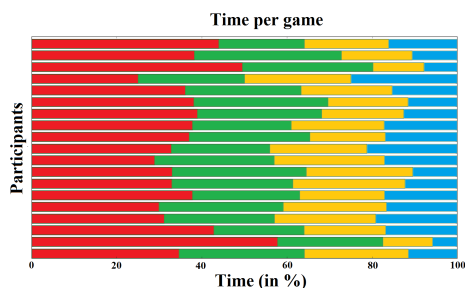


Fig. 2. Percentage of time spent by subjects on the 4 different games.

III. FUTURE WORK

We analyzed data from 13 participants selected among staffs and students at Inria. We observe a different repartition of the time spent per game. Our future work will consist of analysing the reason that could have led the participant to change game (both when and why). We particularly want to investigate whether or not the hypothesis that activity change is related to learning progress.

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