POLYTECHNIC UNIVERSITY HAUTS-DE-FRANCE

LABORATORY OF AUTOMATION, MECHANICS AND INDUSTRIAL AND HUMAN COMPUTER SCIENCE

Visual memory, biometrics and applications to cybersecurity

PhD proposal co-supervised by
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A French version is available at http://koliaza.com/biometrics-thesis-fr.pdf.

Summary

This thesis has two main objectives:

- to rigorously analyse the human ability to recognise previously-seen pictures;

- to optimise the speed at which a computer system can detect such recognition using the pupillary reflex.

Background

The human ability to recognise pictures has been studied since at least the 1960s [9, 7], and is generally highly superior to the ability to recognise and distinguish previously shown words, even multiple months after the initial stimuli. Moreover, this recognition is partially pre-cognitive: when a stimulus is shown, the preprocessing in the visual cortex affects the pupil's dilation, which starts before the subject is aware of the stimulus. It is possible to infer the novelty of the stimulus thanks to this dilation reflex speed [8, 6, 4, 5].

This project follows initial research led by Enka Blanchard and Ted Selker (UMBC) over the last 3 years [2, 1]. Potential candidates[1] should be interested by both computer science (modelisation, data analysis, development) as well as cognitive science (theoretical and empirical). They should have some expertise on at least one of the two fields (Masters level/M2 needed), but we will look at all applications. People with interdisciplinary or non-standard profiles with varied expertise are particularly encouraged to apply.

Research questions and methodology

Depending on the candidate recruited, multiple complementary research leads are imaginable, in the goal of answering some of the following questions:

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[1]All candidates are welcome to apply without discrimination on gender, age, ethnicity or disability status (among others).

- How does the similarity between stimuli affect the pupillary reflex, and how easy is it to create false positives?

- How is picture memorisation affected by the picture type (thematic and stylistic)? What about transformations (cuts, symmetries) or mosaics of multiple pictures?

- Are the performances of the reflex uniform with respect to the conscious memory, especially depending on the variations above?

- How does frequent (or spaced) repetition of a stimulus affect the reflex?

- Would it be possible to infer recognition with a non-negligible probability (»0.5) when pictures are shown at a high speed (0.1-1.0s per picture)?

The research work that is planned involves experiment design (both in controlled conditions and online) to create empirical studies on the questions above. This will then be used to create models of ocular reactions (to obtain a predictive system if possible), followed by empirical validation of said system. Depending on the candidate's profile and abilities, this work could also involve applying the results (for example by creating authentication systems).

The planned first phase of the PhD will be spent partially exploring the existing literature, and organising a first online experiment. This will be followed by experiments in a controlled environment using specialised equipment, starting by a replication of an experiment from the literature. Preliminary data has already been collected and will help guide these initial stages of the PhD.

Potential outcomes

Beyond the theoretical questions, this project is mostly focused on new authentication methods and cybersecurity [2]. However, the results that we seek can be applied to multiple fields and this research has already led to applications in non-electronic secure voting systems [1]. One other lead would be to deepen the cognitive science component to look into the modelisation of memorisation/recognition and mental computing [3].

Supervision

The thesis will be supervised within the Laboratory of Automation, Mechanics and Industrial and Human Computer Science in Valenciennes. The laboratory is staffed by around 110 permanent researchers, 30 permanent engineers, technicians and administrative personel, a dozen postdoctoral researchers and 80 PhD students. The LAMIH is a mixed research unit between the French National Centre for Scientific Research (CNRS UMR 8201) and the Polytechnic University Hauts-de-France. It has four main departments (Automatics, Mechanics, Human and Life sciences, and Computer Science). It has facilities and equipment that will greatly facilitate the biometric experiments that are planned. The thesis will be co-supervised by Enka Blanchard (main advisor) and Antoine Gallais (director and co-advisor).

Antoine Gallais (https://antoine-gallais.github.io/) is full professor (Professeur des Universités) in computer science, member of INSA Hauts-de-France and LAMIH. His research subjects include networks (wireless, IoT, sensors), cybersecurity, performance evaluation and fault-tolerance.

Enka Blanchard (http://koliaza.com) is a transdisciplinary researcher (chargée de recherche — permanent research-only position) at the CNRS in Computer Science, member of the LAMIH since 2021 and associate researcher at the Centre for Internet and Society (UPR 2000). Their research covers multiple fields such as usable security, human-computer interactions, voting systems, discrete mathematics and geographies of disability.

Working conditions and how to apply

The position will be open from January 2022 and will stay open until a good candidate is found. The document at the official address is (http://koliaza.com/biometrics-thesis-en.pdf) and will be amended when the position is filled. This position is also open as a research internship for M2 students as a starting contract.

Candidates with personal/educational/professional obligations during the first half of 2022 are still encouraged to apply in advance. We'd rather find the right candidate and wait for them to be available. The actual work environment is to be discussed, with partial remote work being a possibility (if the candidate wants it), at least during the first few months. The doctoral contract follows the standard set by the French state. It plans for three years of research work, paid 1758€ per month (before taxes, corresponding to about 1400€ in real income[2]). From the second year onwards, this salary can be complemented by teaching at UPHF (200€ extra per month for 64 hours of teaching per year).

To get more information or to apply, please send an email with a CV to enka.blanchard@gmail.com. An online interview will be organised with potential candidates after exchanging a few emails.

References

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[3] Enka Blanchard, Ted Selker, and Florentin Waligorski. Towards an empirical cost model for mental password algorithms. In *Extended Abstracts of the 2020 CHI Conference on Human Factors in Computing Systems*, CHI EA '20, page 1–8, 2020.

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[5] Sean Cody. Do only the eyes have it? Predicting subsequent memory with simultaneous neural and pupillometry data. Master's thesis, The Ohio State University, 2015.

[6] Carlos Alexandre Gomes, Daniela Montaldi, and Andrew Mayes. The pupil as an indicator of unconscious memory: Introducing the pupil priming effect. *Psychophysiology*, 52(6):754–769, 2015.

[7] Geoffrey R. Loftus. Eye fixations and recognition memory for pictures. *Cognitive Psychology*, 3(4):525–551, 1972.

[8] Marnix Naber, Stefan Frässle, Ueli Rutishauser, and Wolfgang Einhäuser. Pupil size signals novelty and predicts later retrieval success for declarative memories of natural scenes. *Journal of vision*, 13(2):11–11, 2013.

[9] Roger N. Shepard. Recognition memory for words, sentences, and pictures. *Journal of Verbal Learning and Verbal Behavior*, 6:156–163, 02 1967.

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[2]This includes multiple benefits that are automatically included in French salaries (such as healthcare), and tuition fees are negligible (200-400€) per year. The cost of life in Valenciennes is pretty affordable for France (e.g., 1-bedroom apartment are available for 400-500€/month.