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Introduction to the special issue "Learning with information technologies: New opportunities"

André Tricot

Laboratoire de psychologie – Epsylon

Université Paul Valéry Montpellier 3

Route de Mende - 34199 Montpellier cedex 5, France

andre.tricot@univ-montp3.fr

In schools, universities or even at home, many people learn daily with information technologies. Today, most of these information technologies are computer-based. In other words, many human beings learn with new devices and the cognitive processes involved in learning have to cope with new demands. For example, when reading and understanding hypertext, web documents, multimedia supports, etc. a learner face several new demands compared to text-based reading and comprehension. Students' collaboration when learning together in the same room involves several different socio-cognitive processes compared to computer-based or distance collaboration. Feedback when provided by a human may be perceived as more threatening than feedback sent by a computer, for certain students; for other students, there is no difference. Learning in real vs. simulated or virtual environment is not the same.

Learning with information technologies is a lively research topic in various scientific disciplines, with several thousand articles published each year. For example, in computer science, the main goal is to model, to implement and to evaluate knowledge-based systems and interactions that support human learning. In education, many investigations try to understand how computer-based education changes the way teachers teach and students learn, inside and outside schools. There is a great deal of other social science and humanities research published on learning with information technologies, in sociology, anthropology, information science, documentation, linguistics and so on. Statistics, data mining and data visualization are involved in the development of learning analytics, trying to uncover the relations between students' behavior (how they use the technology) and students' learning (how their knowledge changes).

So, what is the contribution of psychology? Research in this scientific discipline is dedicated to the investigation of the cognitive (in the broadest sense) processes involved in learning with information

technologies. Applied psychology, especially in instructional design, is very productive in this area, trying to find means to support the processes involved in learning with these new supports. A very important aspect of both basic and applied research in the psychology of learning with new technologies is devoted to students' characteristics (e.g. prior knowledge) and needs (e.g. learning disability).

Psychological research on learning with new information technologies is having a great return effect: much work in this area is producing results and theories that are far more wide-reaching than computer-based education, contributing to major advances in psychology. For example, Richard Mayer's cognitive theory of multimedia learning (Mayer, 2020) is able to explain, in a very general way, how human beings learn with words and pictures (what humans have been doing since long before computers were invented!). On the applied side, the literature on multimedia learning, mostly based on cognitive load theory and working memory models, has uncovered some 15 design principles that can be used by teachers, media designers and publishers (Puma & Tricot, 2021). Jean-François Rouet and colleagues' model of goal-oriented reading and cognitive processing of multiple documents (Rouet, Britt, & Durik, 2017) is another example of the return effect from learning with new information technologies to basic psychological research: cognitive processing of multiple documents is one of the biggest challenges for text comprehension models, because it investigates how readers elaborate a text representation, a situation model… where the situation itself is not necessarily coherent! This empirical and theoretical set of researches started with electronic documents, leading today to a successful cognitive model, but readers have been processing multiple documents for centuries! Daphne Bavelier's research on learning with video games (Bavelier, Green, Pouget, & Schrater, 2012) has a general scope in the field of brain plasticity and, particularly, on how learning based on deliberate practice can have an effect on domaingeneral basic skills like selective attention. There is now a very active psychological research domain on video-game based learning (Bediou et al., 2018), addressing the most basic and difficult question about learning: how do human beings generalize knowledge and skills? Peter Pirolli's information foraging theory (Pirolli, 2017), based on information seeking with on-line tools, like Google and the web, is now a framework for a much more general topic: how do human beings seek information in their environment, deal with it and learn about it?

Thus, psychological research on learning with new technologies is a contribution to both psychology itself, and to learning with new technologies. This special issue tries to show this double contribution, with a focus on new opportunities to learn. One paper present how a set of digital tools provide new opportunity for learners with specials needs, two papers evaluate opportunities to reduce the split

attention effect, and two papers present new ways to promote active learning in enhanced environment.

The paper by Maëla Trémaud and her colleagues is a good example of research investigating learning with new technologies for individuals with special needs. In a participatory longitudinal research-action study (1 year), the authors investigate the effect of a set of digital tools on the development of communication, autonomy and socialization skills. Participants are children with autism spectrum disorder (ASD) associated with intellectual developmental disorder. They are compared to a control group of children of the same age, using more traditional tools, which have proven to be effective. A standardized scale is used to assess the progress of each participant. The results show an advantage in favor of digital tools. Interestingly, thanks to these results, authors outline how a digital tool can change learning: "The main advantage of the digital tool seemed to be the ability to personalize the apps and adapt them to the needs and functioning of each child with ASD which provide an opportunity to respond to the heterogeneous profiles of individuals with ASD […] [the tool] respects the particular perceptual and temporal processing observed in autism more".

Juliette Désiron, Mireille Bétrancourt and Erica de Vries' contribution is a typical research in the domain of multimedia learning. It addresses a central question in this domain: how students integrate multiple sources of information when trying to understand a multimedia document? The "split attention effect" occurs when students must split their attention between multiple sources in one document. Although many results show that split attention has a negative effect on learning, the different ways to reduce the split attention effect are still discussed. Indeed, the classical solutions (temporal and spatial integration of related information; adding signals, like arrows) can overload the presentation and produce confusion. Désiron and colleagues investigate the effect of cross-representational signaling, i.e. an explicit representation of the links between the multiple sources of information. Meta-analysis in this domain show that signaling co-referred information has a positive effect on learning, especially for learners with low prior knowledge and reading abilities. In this study, authors test a cross-representational signaling technique: color coding and picture labelling. Students with low prior knowledge and reading abilities have to read one of the three versions of the same document: multimedia (text and animations) with cross-representational signaling, multimedia without cross-representational signaling and text only. Results show a better learning in the multimedia with cross-representational signaling version.

Salomé Cojean and Nicolas Martin also investigate split attention effect in multimedia learning, but on a different type of document: video with subtitles. When learners try to understand this kind of video, they have to split they attention between oral narration, written text, and visual illustration. Cojean and Martin experimentally tested the reduction of subtitles, by presenting only a few written

keywords instead of subtitles. Participants had to understand one of the four versions of a 12-minutes video: with or without subtitles, and with or without keywords. Results show no effect of subtitles but a negative impact of keywords on learning. Keywords are not enough to support video comprehension, or, as suggested by the authors, learners did not use keywords as relevant scaffolds.

Jean-Christophe Hurault, Adrien Tedesco and Lionel Brunel address another big question in learning with technologies: are new technologies able to support, efficiently, active and immersive learning? One of the most discussed issue in educational psychology during the last 15 years can be formulated like that: is promoting constructivism, embodied and situated sensorimotor activities, actually a good way to increase learning… Or just a way to overload learners' cognitive capacities? New technologies as a way to promote active learning take an important place in this debate. Authors investigated associations between student's sense of agency and learning gain. Learning was based on problem solving in an interactive virtual reality. Students had to solve physical problems by performing motor actions in order to elaborate abstract concepts. Two experiments are presented. Results show an effect of global sense of agency on learning, in virtual reality.

Fabien Bitu, Béatrice Galinon-Mélénec, and Michèle Molina also wrote a paper based on embodied cognition. It addresses the effect of a tool (digital touchscreen, that provide direct finger feedbacks during a drawing task) on creativity. Participants were asked to produce the most original house possible. There are three experimental conditions: drawing on tablet with finger vs. with stylus vs. drawing on paper with a pen. Originality of the drawing is evaluated. Results show no significant difference between drawings made with finger and stylus on tablet, but a significant difference between drawing on paper and on tablet. According to authors, "tablet's positive effect on originality in a drawing task with finger and stylus would […] be explained by the increased use of simulation that would facilitate the process of creativity by generating a wide range of motor actions to be executed. Creativity, mobilizing simulation process, is thus fostered when the prediction mechanism is urged by an increase of kinesthetic information (finger situation) and when this prediction mechanism is essential to compensate for a kinesthetic loss (stylus situation)."

I hope this special issue illustrates how new technologies provide new opportunities for learning and address important psychological questions.

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