

The Users' Manual to the Unconscious Mind

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A few years ago, we were chatting casually about new models for authentication that would better protect critical information, such as student data and personal health records. Our group was composed of research scientists, psychologists, and educational researchers. Some of us worked more in the area of authentication and others in the area of developing new types of knowledge systems that could be integrated into courses and training sessions in ways that improved learning outcomes. Our discussions converged on how to build patient education systems that could provide ongoing support for self-management of chronic illness. Such systems could provide increased data collection on what a patient understood about their disease and how they acted to promote healthy behaviours, but would have to be implemented under strict conditions of protecting the privacy of the patient through access portals that had rigorous authentication barriers. The patient authentication-education models evolved to more generalized models for effective use of computational technologies to create adaptive learning environments that were evidence-based to improve educational outcomes while authenticating the learner. We were struck by the idea that research on the role of the unconscious mind might be critical to models for both authentication and new probes of learning processes as well as later expression of learning expressed in behaviour.

We had become increasingly intrigued by how and why different disciplines offer diverse perspectives on how the unconscious mind should be defined and measured, resulting in a broad range of cognitive abilities that could be labeled unconscious. To explore possible roles of the unconscious mind, we decided to study the feasibility of measuring what we call an individual's Imprint of Unconscious Processing (IUP). One

area of study focused on the feasibility of measuring and using an imprint of an individual's unconscious as a mean to authenticate the individual, for example when signing into a computer or a network¹. The second area focused on the feasibility of measuring and using an imprint of an individual's unconscious to study how the respective individual developed misconceptions during learning that then were expressed during the individual's demonstration of conceptual and performance competencies². While the areas of authentication research and research on misconception development have not previously been linked, two of our research programs began to converge on patterns of unconscious processing. For example, our work in the area of biometric authentication and liveness tests had already touched on aspects of the human mind as features for human identification and we extended this idea to consider the possible uniqueness of individual-specific patterns of unconscious processes, which we called IUPs. During the same time period, we had been studying misconception development as a type of flawed unconscious pattern recognition. We believed this convergence was related to the how and why IUPs might vary through time, with such variation shaped by situated experiences. Our thinking and subsequent research began to meander along a complicated path that explored four areas: (1) the boundaries between the unconscious and the conscious; (2) possible use of the unconscious mind for authentication of an individual; (3) the role of the unconscious in critical knowledge gaps within education, with a specific focus on misconception development; and (4) the future of work on AI, knowledge systems, and human computer interfaces.

Exploring the Boundaries between the Unconscious and the Conscious

As noted above, different disciplines offer diverse perspectives on how the unconscious mind should be defined and measured, resulting in a broad range of cognitive abilities that could be labeled unconscious. In cognitive psychology the unconscious mind has been measured by presenting participants with weak and brief subliminal stimuli that are, by definition, unable to enter the person's phenomenal

¹ K. Jóhannsdóttir, J. Tashiro, M. Vargas Martin, G.B. Reynaga, *The unconscious mind as a means for authentication*, „APA Newsletter on Philosophy and Computers” 2011, in press.

² J. Tashiro, P.C.K. Hung, M. Vargas Martin, *ROAD-MAP for Educational Simulations and Serious Games*, [in:] P. Tsang, S.K.S. Cheung, C.S.K. Lee, R. Huang (eds.), *Hybrid Learning – Proceedings of ICHL* (August 2010), Springer, Beijing 2011, p. 186-204.

consciousness³. Performance in those subliminal detection studies is restricted to responding to simple stimuli such as a single word⁴, indicating the weak power of the unconscious mind⁵. From this perspective, measuring Imprint of Unconscious Processing (IUP), although possible, might not be feasible for authenticating the individual. The rather low-level and simple processing of the unconscious mind might not allow for enough variation in measureable responses to distinguish one individual from another.

In contrast to the approach taken by cognitive psychology, social psychology defines the unconscious mind in terms of cognitive processes that control behaviour without the individual's awareness of those processes or their effect⁶. Following this approach, research has revealed that people are surprisingly unaware of what actually affects and causes their behaviour⁷. This is true not only for low-level information processing but also for more complex behavioural control, like playing chess, solving problems or interacting socially⁸. In fact, unconsciously learned associations between people, events, and affective responses, largely guide our social interaction and social judgments⁹.

Unconsciously learned associations also largely guide our responses on various pattern recognition tasks. In a study by Chun and Jiang¹⁰ participants quickly learned a repeated layout in stimuli and used this information to correct and optimize their responses. The participants, however, had no explicit awareness of the learned pattern or how it affected their behaviour¹¹. This was true even when participants were instructed to pay attention to the repeated layout during the learning phase. In another study, Kirsh and

³ J. F. Kihlstrom, *The cognitive unconscious*, „Science” 1987, No. 237, p. 1445-1452; P.M. Merickle, *Perception without awareness: Critical issues*, „American Psychologist” 1992, No. 47, p. 792-795.

⁴ A.G. Greenwald, *New look III: Unconscious cognition reclaimed*, „American Psychologist” 1992, No. 47, p. 766-799.

⁵ See also: E.F. Loftus, M.R. Klinger, *Is the unconscious smart or dumb?*, „American Psychologist” 1992, No. 47, p. 761-765; A.G. Greenwald, op.cit.; J. F. Kihlstrom, T.M. Barnhardt, D.J. Tataryn, *The psychological unconscious: Found, lost, and regained*, „American Psychologist” 1992, No. 47, p. 788-791.

⁶ J. Bargh, E. Morsella, *The unconscious mind*, „Perspectives on Psychological Science” 2008, No. 3 (1), p. 73-79.

⁷ R. Nisbet, T. Wilson, *Telling more than we can know: Verbal reports on mental processes*, „Psychological review” 1997, No. 84, p. 231-259.

⁸ J. F. Kihlstrom, op. cit., p. 1445-1452; P. Lewicki, T. Hill, M. Czyzewska, *Nonconscious acquisition of information*, „American Psychologist” 1992, No. 47, p. 796-801.

⁹ See for an interesting review: P. Lewicki, T. Hill, M. Czyzewska, op.cit.

¹⁰ M.M. Chun, Y. Jiang, *Implicit, long-term spatial contextual memory*, „Journal of Experimental Psychology: Learning, Memory, and Cognition” 2003, No. 29, p. 224-234.

¹¹ See for similar results: P. Lewicki, T. Hill, E. Bizot, *Acquisition of procedural knowledge about a pattern of stimuli that cannot be articulated*, „Cognitive Psychology” 1988, No. 20, p. 24-37.

Maglio¹² had participants play the highly interactive video game of Tetris. They found that participants' initial interaction with the game (manipulating the blocks as they appeared on the screen) was guided by processes the participants had no conscious access to. When asked, they described various strategies, but strategy descriptions never reflected an awareness of how early manipulation of the blocks influenced performance on the shape-fitting task. In both studies the participants were conscious of the stimuli (the blocks or the pattern in Chun and Jiang's study) but they were not conscious of how the stimuli were affecting their behaviour. Furthermore, the optimized behaviour in either case was not intended.

Following the approach taken in social psychology and in line with the evidence, our definition of the IUP will borrow from Bargh and Morsella's¹³ proposition that "unconscious processes are defined in terms of their unintentional nature and the inherent lack of awareness is of the influence and effect of the triggering stimuli and not of the triggering stimuli". An IUP therefore refers to a particular behavioural or cognitive pattern that is unintended and motivated by information processing and behavioural control that is not consciously accessible to the individual. This unconsciously motivated behavioural pattern is influenced by the individual's past history, experience and learning and can be seen as the individual's signature. From this perspective, the unconscious mind might have a very interesting functional value in authentication systems. It is capable of generating a rich behavioural repertoire making an individual authentication feasible. Any behaviour guidance that the person cannot consciously access (is unconscious) and is unintended falls under our definition of IUP. However, behaviour that is intended but once started falls largely outside of the person's consciousness would not classify as IUP. An example of such behaviour is typing of a skilled typist or driving by an experienced driver.

We believe that the general login of a person with a conventional password falls within default behavioural tendencies similar to the typing of a skilled typist as the conscious mind is more focused on the activities that they are about to work on within the computer environment, beyond the login and authentication. These are efficient

¹² D. Kirsh, P. Maglio, *On distinguishing epistemic from pragmatic action*, „Cognitive Science” 1994, No. 18, p. 513-549.

¹³ J. Bargh, E. Morsella, *op.cit.*, p. 78.

procedural sequelae that are implemented outside of consciousness even though they are intentional. In contrast, our interest here is in cognitive processes and attributes that guide the individual's behaviour but that the individual cannot consciously access and therefore is unable to verbally describe. We also believe that this area of unknown or less well-known unconscious processes are a fertile ground for exploring combinatorics of cognitive and behavioural attributes that could lead to unique authentication of individuals as well as “signatures” of flawed learning and actions based on such flawed learning.

How Do You Know Who I Am?

Some literature¹⁴ and commercial applications (e.g., <http://www.emotiv.com/>) hint that in the not so distant future, human beings may have the option of authenticating with their minds. But how might such authentication work and why should we bother developing such an authentication? Well, we explored a statistical analysis and felt we could make the argument that using an individual's unconscious processes for authentication might provide more unique authentication signatures than many current reliable authentication methods. Furthermore, attacks on protected information might come from a human, an automated computer driven algorithm, or a coupled human-knowledge system methodology trying to hack into protected information by mimicking those who had access rights to the information. Perhaps, the unconscious processes of a person deserving access would be harder to mimic by attacking humans, machines, and coupled human-machine methods.

For example, consider one of the more common unconscious actions we tend to perform: doodling. Doodling is essentially drawing without a purpose. Even without purpose, some doodles become conscious activities and other times the doodling remains the manifestation of unconscious processes. Both conscious or unconscious doodling are most often performed while we are actively thinking about something else, such as a phone call or meeting. Thus, one method of unconscious authentication might be the studying metrics for doodles that occur while in the presence of distracting stimuli that

¹⁴ E.g.: J. Thorpe, P. van Oorschot, A. Somayaji, *Pass-thoughts: Authenticating With Our Minds*, [in:] *Proceedings of the ACSA 2005 New Security Paradigms Workshop* (September 2005), Lake Arrowhead 2005.

engages the user's conscious. Such metrics and data collection on these metrics could lead to identification of Imprints of Unconscious Processes – IUPs – and these could be extracted to create an authentication.

The feasibility of IUPs as a new model for authentication led us to propose and begin studying five main hypotheses¹⁵. We simplify here, but these hypotheses provided a framework in which we could study: (1) *Measurability* – there were IUPs that could be measured; (2) *Uniqueness* – if measurable, the IUPS were unique imprints of an unconscious process or set of unconscious processes; (3) *Usability* – that authentication could be deployed with usability that did not create triggering stimuli provoking alterations of a situated experience of an individual in a way that permuted their expression of their IUP; (4) *Resiliency* – that an IUP or suite of IUPs used for authentication would be infeasible for any other user to intentionally or unintentionally mimic the authenticating IUP; and (5) *Potential for Calibration* – that even if some IUP could be measured for each individual, that such an IUP provided a unique signature, and could be deployed within a usable situated login experience, we also could understand how an IUP varies through time because of the dynamic nature of neurophysiological function, and changes in unconscious and conscious attributes, the imprint can be recalibrated to provide a unique authentication for an individual.

Our preliminary work built a necessary foundation for testing these hypotheses by addressing two important issues: (1) defining the IUP, and (2) estimating the potential for and authentication consequences of temporal variation in the individual's IUPs. We concluded that measurement of IUP must be sensitive to particular unconscious imprints but insensitive to conscious cognition. Such a measure is, of course, determined by how the unconscious mind is defined. As described in the prior section, we developed a workable definition of IUP, exploring the boundaries between unconscious and conscious cognition, and figured out how to more deeply study the Measurability hypothesis, which set the base for testing the other four hypotheses. However, we still had to understand the problems that potential variation in IUPs presents to our work on

¹⁵ K. Jóhannsdóttir, J. Tashiro, M. Vargas Martin, G.B. Reynaga, *The unconscious mind as a means...*, op.cit.; M. Vargas Martin, K. Jóhannsdóttir, G.B. Reynaga, J. Tashiro, M.A. Garcia-Ruiz, *Unconscious mind: Authenticating with something you don't know? Or just an infallible liveness test?*, IEEE Canadian Conference on Electrical and Computer Engineering, 2010, May 2-5, Calgary.

developing unique authentication models. Such variation could manifest as heterogeneity through time or across different situated experiences.

In general, any variation in the individual's IUP poses a challenge to authentication. First, let's assume we can measure an IUP, say IUP_i . We need to know if this IUP_i is stable enough to be measured repeatedly as a way to authenticate the individual. Second, if measurable and stable and not easily permutable, could IUP_i remain stable but become part of conscious processing in ways that revealed its quality and so reduced its effectiveness as an authentication imprint (because in conscious processing it might be revealed to others who then could use that imprint, if they could mimic it). Third, if measurable and stable but permutable by situated experience, how long would integrity of measurement last until the permuted versions of IUP_i were no longer recognized by the measurement algorithms and so authentication failed. Furthermore, if measurable and stable but permutable by situated experience, how long would integrity of measurement last if situated experiences leading to permutations were infrequent.

Some evidence has suggested that learning through repeated exposure with the same or similar tasks could alter an individual's IUP¹⁶. Another area of potential concern is the impact the usability of a particular sign-in system might have on both intrinsic and extrinsic facets of the individual, creating a situated experience that is a complex combinatoric of such facets. Unconsciously controlled behavioural patterns could possibly be altered by factors such as the novelty of the sign-in system, and the ease of use. This would increase the difficulty of mapping the emerging situated behaviour to one or a few members of the individual's IUP set. It is therefore crucial to choose an authentication task intended to measure IUPs that maximizes its stability and minimizes any temporal fluctuations. For example, let's assume that it is viable to measure unconsciously motivated social judgments (i.e. x is bad) as the individual's unique IUP. Here learning might not be an issue as our labeling of certain characteristics as being good or bad is the result of a repeated exposure to certain social events and people over time. But this particular IUP is likely to get altered by life's experiences. In contrast, the individual's performance on certain pattern recognition tasks might not be affected by

¹⁶ E.g.: M.M. Chun, Y. Jiang, *Implicit, long-term...*, op.cit.; P. Lewicki, T. Hill, E. Bizot, *Acquisition of procedural...*, op.cit.

different life-related experiences but IUP as measured here might be distorted due to physiological changes that take place through learning.

The third possibility as mentioned above is the case (or cases) in which neither learning nor situated experience cause fluctuations in the IUP but the IUP and/or the resulting behavioural pattern may over time become consciously accessible. In fact, certain implicitly learned strategies in problem solving are known to become explicit over time¹⁷. If an IUP becomes consciously available, it might both alter the already identified imprint and make the authentication based on that particular IUP more readily available to be forged. Therefore, despite having evidence to back up our hypothesis that IUP can be measured, any further progress in our work rests on our ability to properly: (a) identify a performance measure that would maximize stability and minimize fluctuation, and (b) assuming that there is always some fluctuation present, design an authentication algorithm that would account for the fluctuation as a natural aspect of the individual's IUP.

Identifying a performance measure and designing an authentication system that accounts for temporal variations in the unconscious has not been easy. As a starting point, we have explored Gedanken experiments to clarify complex and confounded issues in the measurement of and temporal variations in unconscious processes. Of course, this approach is borrowed from “thinking experiments” that have been used by many different scientists trying to solve difficult problems with nested and confounded facets (i.e. Schrödinger's cat on quantum indeterminacy, and Maxwell's demon on the possibility of violating the second law of thermodynamics). We cannot here report on all of the work we have done¹⁸. However, we were able to make progress in studying how an authentication program might account for temporal variation in IUPs. And, we began coupling these studies to research on mapping an individual's situated experiences to impacts of such experiences on IUPs and the potential for creating a permutation of IUPs. Such work was a starting point for better understanding of the factors shaping change in

¹⁷ R.S. Siegler, E. Stern, *Conscious and unconscious strategy discoveries: A microgenetic analysis*, „Journal of Experimental Psychology” 1998, No. 127, p. 377-397.

¹⁸ But see: K. Jóhannsdóttir, J. Tashiro, M. Vargas Martin, G.B. Reynaga, *The unconscious mind as a means...*, op.cit.; M. Vargas Martin, K. Jóhannsdóttir, G.B. Reynaga, J. Tashiro, M.A. Garcia-Ruiz, *Unconscious mind: Authenticating...*, op.cit.

neurological function through time, especially those factors shaping unconscious-conscious transitions.

After all, we are interested in an unconscious imprint very infrequently becoming consciously accessible to the individual. By looking at these permutations of IUPs we could get a sense of their variation through time and within different types of situated experiences, and then study how permutations in IUPs might shape the likelihood of an unconscious imprint becoming part of conscious activity.

While the potential fluctuations in IUP over time and across situations represent a challenge to our approach for authentication, we systematically continued to create Gedanken experiments in which we might be able to capture mostly elements that are less likely to fluctuate. The reader will quickly see the difficulties and problems with these types of „what if” studies posited above as Gedanken experiments. However, these „thinking experiments” have benefits in terms of future research design and variable identification. These types of experiments also help reveal the weaknesses and lack of empirical support for initial assumptions as well as the complexities of nesting and confounding, which are certainly evident in the example we have provided. So, we continue to pursue these types of experiments as we study options for use of unconscious imprints for authentication.

Unconscious Development of Misconceptions

Finding a measurable and stable IUP is a critical challenge to authentication. Yet, we feel our preliminary work and progressing through tests of the five hypotheses could lead to methods delineating one or more IUPs that could work as unique identifiers and that could be calibrated as IUPs are permuted through situated experiences. Certainly, authentication based on one or more IUPs would have to be empirically derived as a task suite to properly: (a) identify a performance measure that would maximize stability and minimize fluctuation, and (b) assuming that there is always some fluctuation present, design an authentication algorithm that would account for the fluctuation as a natural aspect of the individual’s IUP. However, are there other IUPs that might give us clues

about what an individual has learned? We mentioned above that learning through repeated exposure to similar tasks might very well alter an individual's IUP¹⁹.

We began to wonder if such work on IUPs also would open interesting doors to studying how people learn and in particular how people develop misconceptions during a learning process. For example, Tashiro, Hung and Vargas Martin²⁰ recently provided a summary of knowledge gaps in education. These gaps provide some insight into the role of the unconscious mind in learning and behaviour based on learning: (1) How do educational environments impact disposition to engage in a learning process? (2) What are the relationships between the level of realism in a learning environment and learning outcomes? (3) How do you define the threshold of experience within an educational environment that leads to measurable learning outcomes? (4) What knowledge domains are developed during learning within educational environments? (5) When individuals work within an educational environment, what knowledge is retained and how stable is retention? (6) What is the disposition to act on the knowledge gained within a learning environment? (7) How well can the knowledge gained in educational environments be transferred? (8) What conceptual and performance competencies can be developed during the learning process while working within an educational environments? (9) How are misconceptions developed during and sustained after working within an educational environment? (10) How do instructor-student and student-student social networks and e-communities impact learning? Certainly, these gaps reveal the complexity of studying „what really works” in education.

Earlier in this paper, we argued from a review of the literature that an IUP could be a particular behavioural or cognitive pattern that is unintended and motivated by information processing and behavioural control that is not consciously accessible to the individual. We also argued that such an unconsciously motivated behavioural pattern could be influenced by the individual's past history, experience and learning. Furthermore, any behaviour guidance that the person cannot consciously access and is unintended falls under our definition of IUP, while behaviour that is intended but once started falls largely outside of the person's consciousness would not classify as IUP. At

¹⁹ E.g.: M.M. Chun, Y. Jiang, *Implicit, long-term...*, op.cit.; P. Lewicki, T. Hill, E. Bizot, *Acquisition of procedural...*, op.cit.

²⁰ J. Tashiro, P.C.K. Hung, M. Vargas Martin, *ROAD-MAP...*, op.cit.

the unconscious-conscious interface, we argue that engaging in learning may be intended but development of misconceptions is not intended. Also, we note from work on transitions in knowledge and skills from novice to expert as well as in evocation of certain types of pattern recognition, there may well be unintended unconscious processing, some of which may manifest as misconceptions.

Interesting examples can be found in many fields, but we are most familiar with healthcare education and practice²¹. Pre-professional nursing students are certainly motivated not to develop misconceptions that may lead to errors in patient care. So the development of misconceptions is unintentional. As nursing students move from novices to experts in clinical practice, clinical judgment is often driven by pattern recognition which has emerged either unconsciously or consciously from the clinician perceiving a diverse array of data streaming from the patient. Some of the pattern recognition is evoked consciously, such as decisions along an algorithm for a particular type of trauma case. However, some pattern recognition appears to be unconscious, bubbling up as an unexpected insight. Some of these insights may be correct, while others flawed (i.e., they were misconceptions).

Again turning to thinking experiments, we tried to parse out different types of unconscious and conscious processing to see if there were IUPs that could give us hints about how misconceptions might be developed. This work led us to speculate that there may be a useful taxonomy of IUPs that would provide an initial framework for systematically studying ideas about types of unconscious processing. The discussions about the disaggregating dimensions of such a taxonomy were driven by looking at what appeared to be fundamental differences between IUPs that might work for authentication and IUPs that might work for studying misconception development. Three promising dimensions emerged that would allow disaggregation of IUP types.

²¹ J. Tashiro, *Ethical Analysis of Publisher and Faculty Roles in Building and Using Electronic Educational Products*, „Journal of Electronic Commerce in Organizations” 2009, No. 7 (1), p. 1-17; M. A. Garcia-Ruiz, J. Tashiro, B. Kapralos, M. Vargas Martin, *Crouching Tangents, Hidden Danger: Assessing Development of Dangerous Misconceptions Within Serious Games For Healthcare Education*, [in:] S. Hai-Jew (ed.), *Virtual Immersive and 3D Learning Spaces: Emerging Technologies and Trends*, p. 269-306, IGI Global, Hershey 2011.

One dimension along which separation could occur is relative stability of an IUP. In this context, we argued that any variation in the individual's IUP used as an authentication suite would pose a challenge to authentication. Yet IUPs related to misconceptions and evocation of related pattern recognition processes may change as an individual experiences more and learns more about their own knowledge deficiencies. A second dimension along which IUPs could disaggregate is the extent to which the IUP becomes part of conscious processing. For IUPs used as part of an authentication suite, becoming part of conscious processing is likely to weaken the integrity of the IUP as a unique identifier because use might be revealed to others who then mimic that imprint. In contrast, part of professional development in any field is ongoing attention to and remediation of possible misconception development. A third disaggregating dimension could be the relative motivation to change behaviours that were linked to IUPs. In the case of authentication, there may be little motivation to change IUPs used for authentication unless authentication has been compromised or if such IUPs were associated with mal-adaptive behaviours that the individual wanted to change. IUPs associated with misconceptions might not be a priority target for change if the behaviours associated with such IUPs were relatively benign. However, there would be increasing motivation to change as the relative negative consequences of an IUP increased, for example, mistakes in clinical judgment driven by unconscious evocation of a particular type of flawed pattern recognition during clinical care that resulted in an adverse medical event.

We then explored a three-dimensional space for these dimensions, which we called: (1) Stability, (2) Unconscious-Conscious Interaction, and (3) Motivation to Change. In Figure 1 A and B, we show simple diagrammatic representations of our taxonomy. In this figure, the dimensions are treated as orthogonal. We are still in the speculative stages of developing and testing the taxonomy and recognize the dimensions may not hold up to rigorous experimentation and even if they did represent a meaningful disaggregation framework the dimensions might not be orthogonal. However, as a starting point, Figures 1 A and B provided a point of departure for our ongoing work on unconscious processing, the unconscious-conscious interface, the possibility that IUPs exist and are measurable, and the possibilities for using IUPs in meaningful ways.

The cell in Figure 1A labeled A represents types of IUPs that have low Stability and low Unconscious-Conscious Interaction. With low stability, and even with little Unconscious-Conscious Interactions, such an IUP may be easily permutable and so not very satisfactory as part of an authentication suite. In the context of misconceptions, Cell A may be IUPs that represent incompletely formed and labile pattern recognition processing that is not much engaged during Unconscious-Conscious Interactions. The cell in Figure 1 labeled B represents a type of IUP that could serve as part of authentication suite, with high Stability and low Unconscious-Conscious Interactions, so not as likely to become accessible to conscious processing and possibly revealed to someone who can mimic it. Cell B IUPs may be stable unconscious portions of a pattern recognition, but again pattern recognition processing that is not much engaged during Unconscious-Conscious Interactions.

Cell C represents IUDs that have Intermediate Stability and Unconscious-Conscious Interactions. IUPs of this type could be used in authentication if the authentication system had recalibration capacities, but increasing Unconscious-Conscious Interactions may increase risk of revealing the authentication suite. In the context of misconception development, IUPs typical of Cell C may represent unconscious components of pattern recognition processes that are being shaped by learning or other situated life experiences. Finally, Cell D is meant to represent IUPs that have high stability and also high Unconscious-Conscious Interactions. The high Stability favors use for authentication, but the high Unconscious-Conscious Interactions raises risk for authentication. In relation to misconception development, IUPs in Cell D could be stable pattern recognition elements that are unconscious but may be evoked during high levels of Unconscious-Conscious Interactions, such as might happen during clinical practice in which a clinician is frequently working with particular types of patients. The pattern recognition may become more consciously applied through time, and may be an accurate pattern response based on the individual's knowledge. Such a response may be based on sound knowledge or on knowledge flawed by misconceptions.

Figure 1A. Taxonomy of IUPs along dimensions of Stability and Unconscious-Conscious Interaction.

Stability	Unconscious-Conscious Interaction			
Low . . High	Low ----- High			
	A			
			C	
	B			D

Source: Authors' own work

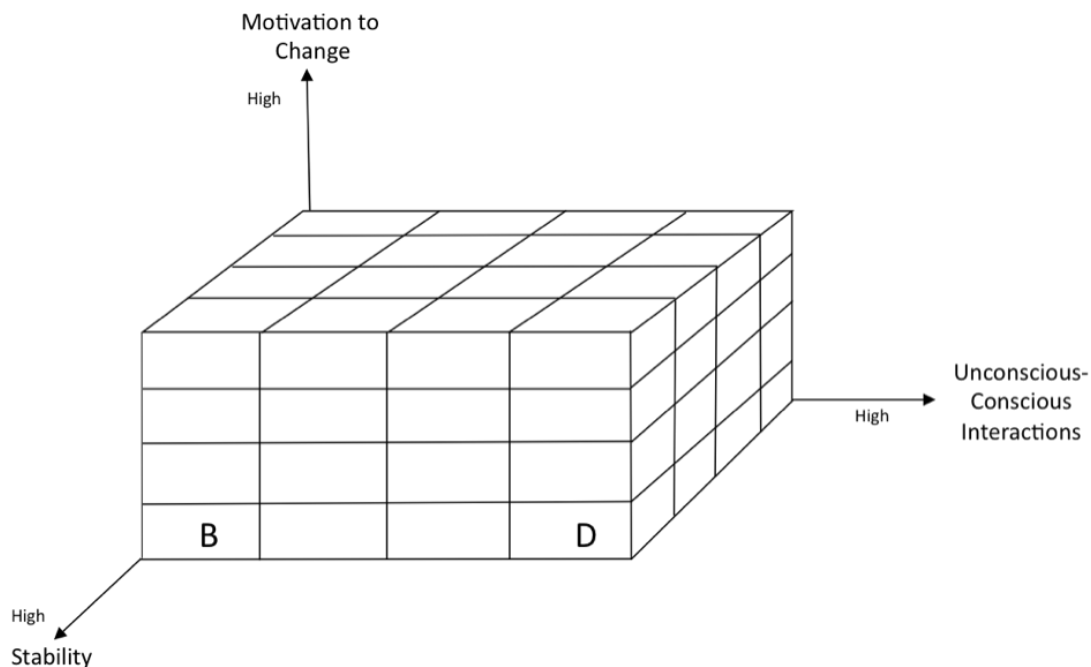
In Figure 1B, we have expanded the taxonomy to include all three dimensions: (1) Stability, (2) Unconscious-Conscious Interaction, and (3) Motivation to Change. This approach effectively adds Motivation to Change to the cells in Figure 1A. For example, Cell A IUPs in Figure 1A are now disaggregated along a gradient of Motivation of Change. So IUPs in Cell A are now parsed into types ranging from Low Stability – Low Unconscious-Conscious Interactions – Low Motivation to Change through Low Stability – Low Unconscious-Conscious Interactions – High Motivation to Change. You also can see in Figure 1B Cells B and D. Cell B in Figure 1B represents those IUPs of Figure 1A Cell B that had High Stability – Low Unconscious-Conscious Interactions – Low Motivation for Change. Analogously, Cell D in Figure 1B represents those IUPs of the Figure 1A Cell D that had High Stability – High Unconscious-Conscious Interactions – Low Motivation for Change.

Within the three-dimensional space of Figure 1B, IUPs that are good candidates for authentication are more likely to be in the region of High Stability – Low Unconscious-Conscious Interactions – Low Motivation to Change. IUPs associated with misconceptions may be scattered throughout the three-dimensional space defined by Stability, Unconscious-Conscious Interactions, and Motivation to Change. Importantly,

the taxonomy we propose provides a framework that we can use to study development of misconceptions and then to remediate misconceptions.

We already have started building and evaluating new types of research environments that would allow us to study the 10 knowledge gaps in education identified by Tashiro, Hung, & Vargas Martin²². Into these research environments, we are now adding engines that can accommodate confounding of variables that could be used to study the 10 gaps. However, we also are adding engines that look for IUPs and map these IUPs to unconscious and conscious cognitive processes. Such mapping is then analyzed in the context of learning outcomes as conceptual competencies and intentions to emit behaviour as performance competencies related to demonstrated conceptual competencies. In brief, we continue to push our studies in the direction of a more unified theoretical framework for what is happening at the unconscious-conscious interface during learning and expression of learning as behaviour.

Figure 1B. The three dimensions for a proposed taxonomy of IUPs with axes of Stability, Unconscious-Conscious Interaction, and Motivation to Change



Source: Authors' own work

²² J. Tashiro, P.C.K. Hung, M. Vargas Martin, *ROAD-MAP...*, op.cit.

Concluding Remarks and Directions for Future Work

The Turing game²³ was perhaps the trigger point that led some modern computer scientists to anthropomorphize artificial intelligence (AI), even though imitating the human mind as an ultimate goal has been criticized as being the result of a collective misinterpretation of the Turing game²⁴. Notwithstanding the challenges, and inspired by the fascination of the human mind, over the years the scientific community has generated a plethora of approaches and proposals for artificial consciousness models and embodied intelligence within the context of AI²⁵. Certainly, the relevance of liveness detection can be found in biometrics or CAPTCHAs (completely automated public Turing test to tell computers and humans apart). In biometrics, liveness detection is utilized to assert that the biometric sample comes from a living individual and not a reproduction of their iris, fingerprint or any other physiological biometric.

The emphasis within cognitive science is on understanding the conscious mind. In contrast, our interest has been more focused on understanding the unconscious mind. We believe that measuring what we refer to as an Imprint of Unconscious Processing (IUP) opens interesting possibilities for studying a range of problems. Herein, we have focused on use of IUPs as a viable option for authenticating the individual for computer security purposes, but also have tried to generalize the framework of IUPs by proposing a taxonomy that allows new models of study for other problems such as misconception development. Our initial work rests on finding: (a) workable definition of the unconscious mind, and (b) ways to capture arrays of an individual's IUPS. Following conclusions drawn from literature in social psychology, we defined the IUP in terms of unintended cognitive processes that guide behaviour without the person being conscious of what is influencing their behaviour. Working out what we mean by an IUP turned out to be the easy part of our work. A much harder problem to deal with is the potential temporal fluctuation in IUP due to learning or various situated experiences. Lack of stability in an IUP over time means that any development of authentication pattern recognition algorithms needs to include capacities for recalibration. And, any

²³ A. Turing, *Computing Machinery and Intelligence*, „Mind” 1950, No. 59, p. 433–460.

²⁴ D. Proudfoot, *Anthropomorphism and AI: Turing's much misunderstood imitation game*. „Artificial Intelligence” 2011 doi: 10.1016/j.artint.2011.01.006.

²⁵ E.S. Brunette, R.C. Flemmer, C.L. Flemmer, *A review of artificial intelligence*, [in:] *Autonomous Robots and Agents, 4th International Conference on Digital Object Identifier*, p. 385–392.

methodologies for study of misconception development need to have capacities for following choices made by a learner with concomitant mapping of these choices to conscious and unconscious processes, as well a association of these processes with learning and behaviour outcomes. Certainly, and consistent with the taxonomy we have proposed, a promising area of study is the conditions under which there is a considerable temporal variation of measurable IUPs and the relationships between temporal heterogeneity and an individual's situated experience.

The literature describes a plethora of technical approaches and proposals for artificial consciousness. For example, Brunette, Flemmer, & Flemmer²⁶ provide a compendium of allusions to robots with consciousness from 1984 to our days, including a classification of approaches from models of consciousness to computational languages and embodied intelligence. Franklin, Baars & Ramamurthy²⁷, distinguish between functional and phenomenal consciousness. They describe the former as an agent whose „... control structure (mind) implements Global Workspace Theory and the LIDA Cognitive Cycle, which includes unconscious memory and control functions needed to integrate the conscious component of the system”. Conversely, they describe phenomenal consciousness as the subjective experience of qualia, i.e., the subjective feel. Under this distinction, it is suggested that extant efforts to gift robots with consciousness (including those found in Brunette et al.) are all aimed at achieving phenomenal (i.e., subjective) consciousness. Despite the accuracy of this distinction, as challenged by Haikonen²⁸, it is yet reasonable to analyze the possibility that artificial consciousness could evolve, naturally or not, or lead into the development of agents with an unconscious mind, and whether this would imply enabling robots with built-in functional unconscious routines that would accordingly dictate the robot's behaviour, or letting their artificial mind develop a phenomenal unconscious on its own, or a combination of the two. Equally important would be to address the potential implications artificial unconsciousness would actually mean and impose in our times, where computers are increasingly used for

²⁶ Ibidem.

²⁷ S. Franklin, B.J. Baars, U. Ramamurthy, *A Phenomenally Conscious Robot?*, „APA Newsletter on Philosophy and Computers” 2008, No. 8 (1).

²⁸ P.O.A. Haikonen, *Slippery steps towards phenomenally conscious robots*, „APA Newsletter on Philosophy and Computers” 2009, No. 8 (2).

supervisory control and data acquisition (SCADA) on which the operation of industrial ecosystems rely such as nuclear plants, assembly lines, refineries, etc.

Without arguing in favour or against any particular definition or modality of consciousness and unconsciousness, it is reasonable to analyze the possibility that artificial consciousness would evolve into the development of artificial unconsciousness. While this evolution could mean the result of explicit human-authored and controlled AI development, we cannot discard the fascinating (and frightening for some) possibility that this evolution could take place naturally as a result of artificial learning routines with unpredictable outcomes. Certainly, popular media has many examples. A small sampling of the authors' favourites include: (1) Isaac Asimov's very interesting fictional excursions into the history of robots, and his classic nine-story collection called „I, Robot” (1950; see also 2004 movie loosely derived on these stories, „I, robot”); (2) the 1982 movie Blade Runner (based on the Phillip K. Dick novel „Do Androids Dream of Electric Sheep”) explored evolving sense of self in replicants; (3) the 1983 movie „WarGames”, which portrays a military mainframe computer with evolving self-awareness that developed a self-protection mechanism to prevent anyone from “unplugging her, which put at risk world stability and leading to a potential catastrophic conflict; and (4) the 2010 movie „Inception” that explores the possibilities of stealing ideas from an individual's unconscious as well as planting an idea into an individual's unconscious that will later bubble up into consciousness and be expressed as behaviour. No doubt readers will have other favourite science fiction media presentations of evolving AI, for good or bad, in computers, robots, androids, avatars, and so on.

The level of dependency of our modern society on computers and the potential reality of artificial consciousness and unconsciousness raises, or at least should raise, serious concerns not only related to public safety but more particularly to the area of biometric authentication within the context of computer security. Thus, if the relationship between artificial consciousness and computer security is now seemingly distant, the area of biometric authentication and liveness tests are already touching on aspects of the human mind as features for human identification. With this framework in mind, the Turing game will now consist of telling apart human from artificial consciousness or unconsciousness and we believe that in a not so distant future, human beings will be able to authenticate

with their minds. We endeavour to think that forging someone's consciousness or unconsciousness could be as infeasible as cracking someone's conventional password using a brute force attack. Regardless of how far consciousness or unconsciousness authentication goes, it is now worth analyzing the hypothetical scenario of having to distinguish between a robot's and a human's unconsciousness, and the potential consequences of breaching the human mind in ways that, perhaps, earlier generations of computer scientists did not anticipate.

In regards to authentication and also our study of misconception development, our current work has begun to focus on moving beyond Gedanken experiments to actual measurements of an IUP and the study of the stability of IUPs. Certainly, functional neuroimaging methodologies that provide data on neurological sequelae and brain area localization are becoming increasingly important in understanding complex relationships among conscious and unconscious processes and their correlates with what an individual is thinking about or doing (e.g., PET, Multichannel EEG, fMRI, and emerging combinations of methodologies and instrumentation). Neuroimaging methodologies may provide a foundation for finding an IUP or set of IUPs that could have value as an authentication. Furthermore, such studies could follow IUPs through time to study temporal heterogeneity. Indeed, advances in data mining may provide means to delineate distributed patterns of brain activity during unfolding of different types of unconscious processes. Interestingly, and in the context of developing an authentication model, we have to find the minimal set of combinations of unconscious processes that can be used as a resilient authentication system, and with the important concomitant that the authentication process cannot significantly alter the unconscious processes that are being used for authentication (a kind of uncertainty principle for measuring the unconscious).

However, the study of misconception development requires coupling of studies of conscious and unconscious processes and research on such coupling requires new types of research environments. Consequently, we have narrowed our studies to examining how and why measuring of temporal variations in unconscious processes requires suites of pattern recognition programs that can be recalibrated by meta-levels of interpretive frameworks that accurately assess the situated experience of an individual during work within an educational environment. Furthermore, the individual's responses within

a particular situated experience need to be mapped to the measurable IUPs for that individual in the respective situated experience. The situated experience of an individual within an educational environment as well as within an authentication process could be shaped by intrinsic and extrinsic factors. The usability of educational environments and authentication systems could impact both intrinsic and extrinsic facets of the individual and create a situated experience that was a complex combinatoric of such facets. This would increase the difficulty of mapping the emerging situated experience to one or few elements of the individual's IUP set. We would have to consider the probabilities of loss of resiliency in authentication when one individual's IUP set was large. And, we would have to consider the enormous number of possible IUPs and their various cross-neurological connections within unconscious processing, conscious processing, and unconscious-conscious interactions.

However, if IUPs can be placed in a meaningful taxonomy, the deeper study of such a taxonomy and extension to an n-dimensional space or unconscious-conscious interactions will raise some interesting issues that should be of importance to authentication processes, teaching and learning, and we believe also to both AI and philosophy. Perhaps the most obvious issue in our research focus is the potential for misrepresenting an individual as we measure that individual's unconscious mind as a means to authenticate that individual or to understand their processes of misconception development.

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