BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 ▪ Fax +32 2 230 59 12
www.belspo.be

Interuniversity Attraction Poles (IAP)
Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION I

Information on the network

To be filled in by the network coordinator

Attention: Before filling in this submission form, please read carefully the information document of the call

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words): **Mechanisms of conscious and unconscious learning**	
Proposal's acronym:	**COOL**
Name of the coordinator: Institution:	**Axel Cleeremans** **Université Libre de Bruxelles**

Code (Reserved for BELSPO):

FORM A: NETWORK COMPOSITION

BELGIAN PARTNERS

Coordinator : Partner 1 (P1) Name : Axel CLEEREMANS Institution : Université Libre de Bruxelles Institution's abbreviation :ULB
Partner 2 (P2) Name : Jan DE HOUWER Institution : Universiteit Gent Institution's abbreviation :UG
Partner 3 (P3) Name : Marcel BRASS Institution : Universiteit Gent Institution's abbreviation :UG
Partner 4 (P4) Name : Tom BECKERS Institution :Katholieke Universiteit Leuven Institution's abbreviation :KUL
Partner 5 (P5) Name : Bruno ROSSION Institution :Université Catholique de Louvain Institution's abbreviation :UCL

INTERNATIONAL PARTNERS

International Partner 1 (INT1)	International Partner 2 (INT2)
Name :Patrick HAGGARD Institution :University College London Institution's abbreviation : UCLondon Country :United Kingdom	Name :Zoltan DIENES Institution : University of Sussex Institution's abbreviation : USussex Country :United Kingdom

FORM B: PROPOSAL SUMMARY

The overarching goal of this project is to contribute to our understanding of the mechanisms of conscious and unconscious learning. Learning, that is, the ability to respond adaptively to changing circumstances is a fundamental ability for any organism. Thanks to recent advances in imaging methods, it has now become clear that the brain is a fundamentally plastic organ, the functional architecture of which is continuously modified through experience. From this perspective, one could thus argue that learning is a mandatory consequence of information processing: We learn all the time, whether we intend to or not. Learning takes many different forms. For instance, contrast learning the fact that Steve Jobs has just passed away with learning how to perform the complex movements involved in dancing the flamenco. Consider the differences between learning how to solve an arithmetic problem with learning a second language. Contrast a baby learning how to walk with an adult learning to play tennis, or a rat learning to avoid an electric shock with a human learning about the Hundred-years War.

In all such cases, one can see similarities, but also differences. All such cases involve changing the representational and behavioural repertoire of an agent, but each seems to appeal to fundamentally different processes. An important consequence of this diversity is that research on learning continues to be unproductively **segregated into distinct subfields** that entertain little communication with each other. For instance, research on implicit learning — the process whereby one learns without intending to do so and without awareness that one has learned, has so far made little contact with research on high-level, conscious learning such as involved in causal reasoning or in problem solving. Likewise, research dedicated to understand the basic mechanisms of learning in animals such as rodents remains almost completely disconnected from research dedicated to understanding basic mechanisms of learning in humans.

The domain as whole also remains **very controversial**. At least three such continuing controversies can be identified. The **first** concerns whether learning depends on associative mechanisms, on effortful, intentional, propositional-like reasoning processes or on a combination of both. Experimentally, recent, controversial evidence has indicated that even animals such as rats can exhibit inferential processing, thus questioning one of the fundamental tenets of associative theories. Conceptually, some theories in the domain assume that all learning is based on associative learning (e.g., connectionism), others assume that all learning is based on the manipulation of propositional symbol structures, and yet others assume that the two kinds of processes operate jointly or that they compete with each other. The second controversial issue is the role that awareness plays in learning, and in particular, the extent and limits of what can be learnt without awareness. The third controversial issue concerns the respective role of top-down and bottom-up learning mechanisms and the nature of their interactions (i.e., are phenomena such as conditioning penetrable to instructions?) Crucially, the poles of these different distinctions are often cast as correlated. Thus, we have one system that learns associations, automatically, in the absence of awareness, and that involves mostly bottom-up processes. The second system, by contrast, learns through hypothesis testing and inference, results in propositional representations that are available to consciousness, and involves top-down mechanisms.

Here, **we propose to fundamentally reconsider the distinction**. Instead of assuming that associative learning is always unconscious, automatic and bottom-up and that cognitive learning is always conscious, effortful and top-down, we propose instead that mechanisms of change operate continuously, at all levels of the cognitive hierarchy as well as over different times scales (i.e., over the time course of a single trial, over learning, and over development). From this perspective, the brain is continuously and unconsciously learning to anticipate the consequences of action or activity on itself, on the world, and on other people. There is considerable evidence for such predictive mechanisms in the human brain[1]. This idea, in fact, forms the core of the Bayesian perspective on information processing and is at the heart of Friston's free energy principle[2], according to which the brain continuously attempts to minimize "surprise" or conflict by anticipating its own future activity based on learned priors.

In this light, we will focus on exploring three central lines of research, as follows:

The **first issue** concerns the computational mechanisms and the neural correlates that subtend associative and cognitive learning, as well as their interactions. One set of questions concerns the extent and limits of each type of learning. Do associative learning mechanisms have sufficient power to account for *all* learning? Humans and animals share much of their neural organization, but also differ in many ways, most significantly perhaps through the fact that the former can leverage the expressive power of language to use and share symbolic structures through

culture, so that they can, for instance, learn much more efficiently through instruction. Conversely, is there evidence for the involvement of symbolic, propositional-like representations in organisms that have typically been considered unable to carry out inferential processes? A second set of questions concerns the dynamics that underlie the transition between associative and cognitive learning (e.g., insight ; the role played by the sleep-wake cycle in consolidating memories ; the mechanisms of automatization in skill learning). There is a genuine puzzle involved in understanding how one can go from associative, subsymbolic learning to full-fledged cognitive learning[3]

The **second issue** concerns the relationships between awareness and learning. There continues to be considerable debate about the extent to which humans can learn without awareness, particularly in domains such as conditioning or implicit learning. Here, we will systematically probe the limits of what can be learned without awareness. The role that consciousness plays in learning, and, conversely, the role that learning plays in shaping the contents of consciousness, are fundamental, yet wholly unsolved issues. Are the mechanisms involved in conscious and unconscious learning subtended by the same or by distinct neural structures? What are the limits of learning without awareness? What is the influence of high-level, conscious processes on lower-level phenomena such as conditioning or habituation? How do we best characterize the differences and commonalities between human and (presumably unconscious) animal learning?

A **third issue** concerns the respective influences of top-down vs. bottom-up processes and their interactions. Functions like executive control and attention are typically considered to involve "top-down" mechanisms associated with awareness, but there is now both evidence for the possibility of unconscious executive control[4] as well as evidence for the fact that attention can dissociate from consciousness[5]. Particular emphasis will be put on understanding (1) how high-level processes such as reasoning, instruction-following and awareness can modulate lower-level, associative learning, and (2) how low-level, unconscious learning can shape further conscious, intentional processing, such as involved in decision-making or in action.

These lines of research will be addressed over a series of eight interconnected work packages that are specifically aimed at leveraging the respective expertise of the partners. The network comprises experts on consciousness (**P1** ULB—Cleeremans), on sleep and memory (**P1** ULB—Peigneux), on language development (**P1** ULB—Content), on literacy (**P1** ULB—Kolinsky), on associative learning and evaluative conditioning (**P2** UG—De Houwer), on intentional action and cognitive control (**P3** UG—Brass), on animal learning (**P4** KUL—Beckers) and on vision and perception (**P5** UCL—Rossion).

Further, the network has solicited the expert collaboration of two foreign partners: Pr. Patrick Haggard (**INT1**, University College London) for his expertise on volition and action, and Pr. Zoltan Dienes (**INT2,** University of Sussex) for his expertise on implicit learning and unconscious processes. Both partners already have several existing links with the Belgian partners, including grants and publications. All partners know each other very well, having often already collaborated with each other. They not only share a deep interest in the importance of learning and plasticity in their respective domains but also have complementary skills and areas of expertise that will be leveraged to their full effect in this project. All have already received the full support of their respective institutions.

COOL is structured in eight workpackages (WP), each placed under the responsibility of one of the partners. The proposed research is strongly driven by a coherent novel perspective on how one should conceive of the traditional dichotomies described above, and addresses the fundamental role that conscious and unconscious learning play in different domains (e.g., memory, face perception, perceptual learning, literacy, animal learning, conditioning, decision-making, habituation, implicit learning, subliminal perception, volition). This innovative vision will result in an important step forward in understanding the fundamental ability of humans and other organisms to adapt to an ever-changing environment.

FORM C: OBJECTIVES, MOTIVATION AND STATE OF THE ART

COOL aims to contribute to our understanding of the mechanisms of learning. Learning, that is, the ability to respond adaptively to changing circumstances is a fundamental ability for any organism. Thanks to recent advances in imaging methods, it has now become clear that the brain is a fundamentally plastic organ, the functional architecture of which is continuously modified through experience. From this perspective, one could thus argue that learning is a mandatory consequence of information processing: We learn all the time, whether we intend to or not.

Learning takes many different forms. For instance, contrast learning the fact that Steve Jobs has just passed away with learning how to perform the complex movements involved in dancing the flamenco. Consider the differences between learning how to solve an arithmetic problem with learning a second language. Contrast a baby learning how to walk with an adult learning to play tennis, or a rat learning to avoid an electric shock with a human learning about the Hundred-years War.

In all such cases, one can see similarities, but also differences. All such cases involve changing the representational and behavioural repertoire of an agent, but each seems to appeal to fundamentally different processes. In particular, a long-standing distinction is that between associative theories and higher-order cognitive theories of learning (see Mitchell, De Houwer, & Lovibond, 2009[6], for a recent instance of the debate). The former assume that cognitive systems learn about the relationships between different events by forming links between the corresponding mental representations. Phenomena such as conditioning, evaluative conditioning, instrumental learning or causal learning have all been taken to involve the operation of such mechanisms. Such learning is often assumed to proceed automatically and in the absence of awareness.

Higher-order cognitive theories of learning, on the other hand, assume that cognitive systems learn by means of effortful, intentional, and inferential processes that result in the emergence of conscious propositional structures that characterize the relationships between different events in a symbolic manner.

This important distinction between, roughly, two broad classes of competing learning mechanisms, is both long-standing and controversial. Some authors, indeed, have argued that the phenomena best accounted for by associative learning theories often turn out to be better explained by higher-order cognitive theories[7]. Others have defended the idea that the two systems operate in parallel, or that they compete with each other.

This debate is also reflected in computational modelling. Thus, connectionist models, which learn exclusively by means of associative mechanisms, have been offered as an alternative to the hypothesis-driven approaches to learning that are characteristic of classical models of information processing (e.g., SOAR, ACT-R). Other models explicitly acknowledge the importance of the two classes of mechanisms and therefore have a hybrid character. Within the connectionist literature itself, the distinction between supervised and unsupervised learning can also be taken to reflect fundamentally different processes. O'Reilly and Munakata [8] have interestingly characterized this distinction as a contrast between <u>model learning</u> (Hebbian, unsupervised learning) and <u>task learning</u> (error-driven, supervised learning). Their analysis is framed in terms of the different computational objectives the two types of learning fulfill: Capturing the statistical structure of the environment so as to develop appropriate models of it on the one hand, and learning specific input-output mappings so as to solve specific problems (tasks) in accordance with one's goals on the other hand.

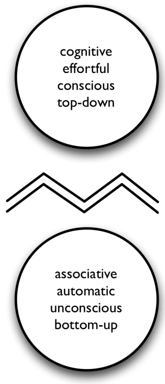
Finally, when one turns to the brain, one finds, somewhat discouragingly, that the only known mechanisms of neural plasticity are long-term potentiation (LTP) and long-term depression (LTD), both of which involve changes to synaptic efficacy and appear essentially associative in nature.

One would think that this new emerging understanding of the role that neural plasticity plays in shaping information processing may unify the field. And yet, extant research on learning continues to be unproductively **segregated into distinct subfields** that entertain little communication with each other. For instance, research on implicit learning — the process whereby one learns without intending to do so and without awareness that one has learned, has so far made little contact with research on high-level, conscious learning such as involved in causal reasoning or in problem solving. Likewise, research dedicated to understand the basic mechanisms of learning in animals such as rodents remains almost completely disconnected from research dedicated to understanding basic mechanisms of learning in humans. This balkanization of learning research into disconnected subfields is undoubtedly the result of the continuing tension between associative and cognitive theories of learning.

Thus, the domain as whole also remains **very controversial**. At least three such continuing controversies can be identified. The **first** concerns whether learning depends on associative mechanisms or on effortful, intentional, propositional-like reasoning processes. Some theories assume that all learning is based on associative learning (e.g., connectionism), others assume that all learning is based on the manipulation of propositional symbol structures, and yet others assume that the two kinds of learning mechanisms operate jointly or that they compete with each other. Likewise, while most theorists would defend the idea that basic phenomena such as conditioning or associative learning are rooted in elementary associative learning processes, others have argued that they instead involve high-level, propositional-like processes even in elementary organisms. A further puzzle in this respect is how the transition between associative and propositional learning is achieved; in particular, whether all information processing can be rooted in subsymbolic, association-based mechanisms or whether there are fundamental qualitative differences between subsymbolic and symbolic processing.

The **second** issue concerns the role that awareness plays in learning, and in particular, the extent and limits of what can be learnt without awareness. This is undoubtedly one of the most controversial issues in the cognitive neurosciences. There continues to be considerable debate about the extent to which humans can learn without awareness, particularly in domains such as conditioning or implicit learning. In this respect, while many authors would accept the idea that human learning can proceed without awareness, convincing evidence remains scant.

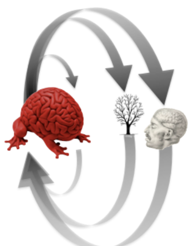
The **third** issue concerns the relationships between top-down and bottom-up processes in learning. The underlying theoretical issue is how one should think of interactions between low-level and high-level processing. Can high-level beliefs influence low-level processing such as motor planning? A related issue pertains to the differences between human and animal learning. Humans and animals share much of their neural organization, but also differ in many ways, most significantly perhaps through the fact that the former can leverage the expressive power of language to use and share symbolic structures through culture, so that they can, for instance, learn much more efficiently through instruction.



F1: Two independent information processing systems

The poles of these different distinctions are often taken to covary systematically. Thus (see **F1**), we have one system that learns associations, automatically, in the absence of awareness, and that involves mostly bottom-up processes. The second system, by contrast, learns through hypothesis-testing and inference, results in propositional representations, and involves top-down processes. Numerous existing theories of information processing in general assume the existence two independent systems between which there is little or no interactions[9,10].

Here, we propose to fundamentally reconsider the distinction. Instead of assuming that associative learning is always unconscious, automatic and bottom-up and that higher-order cognitive learning is always conscious, effortful and top-down, we propose instead that mechanisms of change operate continuously and at levels of the cognitive hierarchy. From this perspective, the brain is continuously and unconsciously learning to anticipate the consequences of action or activity on itself, on the world, and on other people. There is considerable evidence for such predictive mechanisms in the human brain[1]. This idea, in fact, forms the core of the Bayesian perspective on information processing and is at the heart of Friston's free energy principle[2], according to which the brain continuously attempts to minimize "surprise" or conflict by anticipating its own future activity based on learned priors.

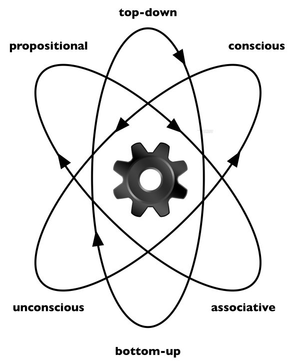


F2: Tangled Loops

Thus, we have three closely interwoven loops (**F2**) all driven by the very same prediction-based mechanisms. A first, internal or **"inner loop",** involves the brain redescribing its own representations to itself as a result of its continuous unconscious attempts of predicting how activity in one region influences activity in other regions. In this light, consciousness amounts to the brain's performing signal detection on its own representations[11], so continuously striving to achieve a coherent (prediction-based) understanding of itself. It is important to keep in mind that this inner loop in fact involves multiple layers of recurrent connectivity, at different scales throughout the brain. A second **"perception-action loop"**, results from the agent as a whole predicting the consequences of its actions on the world. The third loop is the **"self-other loop"**, and links the agent with other agents, again using the exact same set of mechanisms as involved in the other two loops. Some of us have argued that the existence of this third loop is constitutive of conscious experience for it is in virtue of the fact agents are constantly attempting to model other minds that they become able to develop an understanding of themselves. In other words, in the absence of such a "self-other loop", the system can never bootstrap itself into developing the (implicit, embodied, transparent[12] model of itself that forms the basis, through Higher-Order Theory (HOT), of conscious experience.

The processing carried out by the inner loop is thus causally dependent on the existence of both the perception-action loop and the self-other loop, with the entire system thus forming a "tangled hierarchy" (e.g., Hofstadter's concept of "a strange loop"[13]) of predictive internal models[14,15]. The hypothesized "tangled" character of the three loops is more than a mere play of words, for it is precisely what makes it possible for cultural, high-level beliefs to influence what happens at much more elementary levels of description. Conversely, it is in virtue of the operation of the "inner loop" that low-level processes of neural plasticity can exert their influence on high-level processes.

From this conceptual starting point, the distinctions spelled out above between (1) associative vs. cognitive learning, (2) conscious and unconscious processing, and (3) bottom-up vs. top-down processing are not necessarily systematically associated with each other. Thus, rather than assuming the existence of a sharp boundary between one learning and representational system and the other, we instead surmise (1) that each results from mechanisms of change that operate continuously at different levels of the cognitive hierarchy, and (2) that such mechanisms of change can be independently characterized along three dimensions: associative vs. propositional learning, conscious vs. unconscious learning, and top-down vs. bottom-up learning (see **F3**)



F3: Three interacting dimensions of information processing

This position has the substantial implication that the three dimensions we consider may dissociate. Thus, for instance, we surmise that high-level, propositional beliefs can *unconsciously* influence low-level processing such as that involved in programming the motor system[16] or how fast we make decisions in conflict situations. Likewise, presumably unconscious organisms such as rats can carry out high-level processing akin to inferential judgments. Rules — symbolic structures per excellence — can be learnt without awareness, and likewise, associative mechanisms can apply to propositions.

Beyond the theoretical reasons spelled out above that motivate the project's focus on the mechanisms of learning, there is another, equally important, methodological reason to do so: Studying the effects of change on behaviour informs us about the relationships between performance, awareness, and metacognition in ways that any approach using "static" paradigms cannot hope to achieve because the dynamics of learning can be exploited to enable more sophisticated inferences. For instance, if learning can change subjective experience, we need to change the methods we use when exploring unconscious cognition, for anecdotal reports show that the vast majority of experimenters who design subliminal perception experiments can actually see the subliminal stimuli they claim remain invisible to participants! Learning can thus create as well as eliminate contents from phenomenal experience. Tasting wine for the first time is a wholly different experience than that of an oenologist[17], whose phenomenology has been enriched through expertise. Expertise, crucially, can also eliminate phenomenal contents from awareness, as in the well-known 'find the F's" illusion, in which observers surprisingly find themselves unable to count the number of instances of the letter "F" that occur in a text fragment. Here, reading expertise has eliminated function words from awareness. There are many other examples of such "predictive attenuation" mechanisms: Tickling one's self is far less effective than being tickled[18], for when we tickle ourselves (but not when we are tickled) our brain can predict the consequences of our actions. Cognitive development also highlights how some changes go unheeded (i.e., the fact that our action and perceptual systems remain adapted despite our limbs growing spectacularly during the first few years) whereas other changes have profound phenomenal consequences (i.e., learning to read).

Thus, in the proposed studies, we seek to invent novel methods to uncover interesting patterns of association and dissociation between these different dimensions. We do this in different domains that engage different levels of the hierarchy: From basic perceptual processes all the way to cultural learning.

In this light, **the overarching goal of this project is to contribute to our understanding of the relationships between conscious and unconscious learning**. Any time that any animal learns anything, something must change somewhere in the brain (Kandel[19]). The search for this "engram" has been among the most enduring and compelling strands in the history of both psychology and neuroscience. COOL represents a concerted, and innovative research attack on this question, with the additional key twist: to what extent, if any, are these mechanistic changes in the brain associated with our experience of what we learn. We will focus on exploring three central lines of research, each addressing one of the controversies described above, as follows:

The **first issue** concerns the computational mechanisms and the neural correlates that subtend associative and higher-order cognitive learning, as well as their interactions. One set of questions concern the extent and limits of each type of learning. Do associative learning mechanisms have sufficient power to account for *all* learning? Humans and animals share much of their neural organization, but also differ in many ways, most significantly perhaps through the fact that the former can leverage the expressive power of language to use and share symbolic structures through culture, so that they can, for instance, learn much more efficiently through instruction. Conversely, is there evidence for the involvement of symbolic, propositional-like representations in organisms that have typically been considered unable to carry out inferential processes? A second set of questions concerns the dynamics that underlie the transition between associative and cognitive learning (e.g., insight ; the role played by the sleep-wake cycle in consolidating memories ; the mechanisms of automatization in skill learning). There is a genuine puzzle involved in understanding how one can go from associative learning to higher-order cognitive learning[3].

The **second issue** concerns the relationships between awareness and learning. There continues to be considerable debate about the extent to which humans can learn without awareness, particularly in domains such as conditioning or implicit learning. Here, we will systematically probe the limits of what can be learned without awareness. The role that consciousness plays in learning, and, conversely, the role that learning plays in shaping the contents of consciousness, are fundamental, yet wholly unsolved issues. Are the mechanisms involved in conscious and unconscious learning subtended by the same or by distinct neural structures? What are the limits of learning without awareness? What is the influence of high-level, conscious processes on lower-level phenomena such as conditioning or habituation? How do we best characterize the differences and commonalities between human and animal learning.

A **third issue** concerns the respective influences of top-down vs. bottom-up processes and their interactions. Functions like executive control and attention are typically considered to involve "top-down" mechanisms associated with awareness, but there is now both evidence for the possibility of unconscious executive control[4] as well as evidence for the fact that attention can dissociate from consciousness[5]. Particular emphasis will be put on understanding (1) how high-level processes such as reasoning, instruction-following and awareness can modulate lower-level, associative learning, and (2) how low-level, unconscious learning can shape further conscious, intentional processing and decision-making.

These lines of research will be addressed over a series of interconnected work packages that are specifically aimed at leveraging the respective expertise of the partners. The network comprises experts on consciousness (**P1** ULB—Cleeremans), on sleep and memory (**P1** ULB—Peigneux), on language development (**P1** ULB—Content), on literacy (**P1** ULB—Kolinsky), on associative learning and evaluative conditioning (**P2** UG—De Houwer), on intentional action and cognitive control (**P3** UG—Brass), on animal learning (**P4** KUL—Beckers) and on vision and perception (**P5** UCL—Rossion). Further, the network has solicited the expert collaboration of two foreign partners : Pr. Patrick Haggard (**INT1**, University College London) for his expertise on volition and action, and Pr. Zoltan Dienes (**INT2,** University of Sussex) for his expertise on implicit learning and unconscious processes. All partners have already received the full support of their respective institutions, and have highly complementary skills, the combination of which will be essential to carry out the proposed research. The project will leverage all available methods of cognitive neuroscience, from electrophysiology and brain imaging to behavioural methods and computational modelling.

Specific research directions to be pursued include the following:

The mechanisms of memory consolidation. The human face conveys and reveals a wide variety of information about an individual (identity, sex, age, mood, etc.), and the extraction of this information is critical for social interactions. Distinguishing individual faces, in particular, requires elaborate and refined perceptual skills call for by few other categories of objects, so that the faces is a fantastic category of stimulus to study the functional and neural basis of perceptual learning. They are very few if any stimuli in the environment that we are exposed to and learn as much, and as well, as faces. Learning of faces involves no formal training and proceeds quasi automatically during all of our life. However, surprisingly, the factors and dynamics subtending the creation of face representations in the human brain are scarcely studied. In **WP1**, **P5** (UCL—Rossion) and **P1** (ULB—Peigneux) (ULB) will collaborate to explore the neuro-functional mechanisms of conscious and unconscious memory acquisition, as well as post-training consolidation for novel faces.

The mechanisms of associative learning and conditioning. Dominant theories of learning and memory are rooted in animal studies. It has long been thought that animal research makes it possible to study processes of learning, consolidation and memory in the absence of the higher-level processes found in humans. However, recent research has suggested that classical conditioning in animals such as rats may rely on rather sophisticated, propositional-like processes, much like the processes that operate in the learning of stimulus relations in humans. In **WP2**, **P4** (KUL—Beckers), **P2** (UG—De Houwer) and **P1** (ULB—Cleeremans, Peigneux & Kolinsky) will pursue the idea that seemingly basic associative learning phenomena may reflect sophisticated causal inference skills in animals. In another series of studies, the same teams will pursue recent developmental studies that suggest that the development of causal learning goes hand in hand with the development of particular inferential reasoning and working memory abilities that are important for human causal learning according to a propositional approach to associative learning.

Interactions between top-down and bottom-up learning. Here, we will focus on documenting and exploring interactions between high-level, intentional processes and lower-level, unintentional, unconscious processes. Different avenues of research will be pursued to address this issue. Thus, **WP3**, carried out by **P2** (UG—De Houwer) in collaboration with **P1** (ULB—Cleeremans), **P3** (UG—Brass) and **P4** (KUL—Beckers), will explore the properties of habituation and conditioning via verbal instructions. A second line of research will be pursued in **WP5**, where **P3** (UG—Brass), in collaboration with **P1** (ULB—Cleeremans) and **INT1** (UCLondon—Haggard) explores the respective influence of conscious and unconscious learning processes on decision making, leveraging recent pattern classification of fMRI data (MPVA) to quantify the influence of unconscious sources. Further planned studies, to be carried in **WP7** by **P1** (ULB—Cleeremans) in collaboration with **P3** (UG—Brass), **P5** (UCL—Rossion), **INT1** (UCLondon—Haggard) and **INT2** (USussex—Dienes) will examine the impact of hypnosis, suggestion, or placebo on learning, as well as computational modeling of the differences between conscious and unconscious learning. Finally, **WP8**, lead by **P1** (ULB—Kolinsky) in collaboration with **P5** (UCL—Rossion) and **P2** (UG—De Houwer), is dedicated to the feedback effects from newly acquired, cultural knowledge such as reading and writing (which might be considered as a "secondary ability") on the phylogenetically and ontogenetically older biological system of spoken language and nonlinguistic vision. Literacy deeply impacts on the brain organization of the speech and vision systems by inducing neural competition with other visual categories, mainly faces. Yet, the behavioral consequences of some of these neural effects, as well as their developmental course, are still unknown. Further studies will be dedicated to studying beginning readers, either child or illiterate adults, including in longitudinal designs.

The limits of unconscious learning. In this line of research, we will systematically explore the boundaries of what we can learned without awareness. Fields such as conditioning, evaluative conditioning, implicit learning, and decision-making all remain characterized by continuing controversy about the nature and extent of unconscious influences on learning and on processing. Different avenues of research will be pursued to address these issues. **WP4** led by **INT2** (USussex—Dienes) in collaboration with **P1** (ULB—Cleeremans) and **P4** (KUL—Beckers), will explore (1) whether learning can take place with subliminal stimuli, and (2) whether abstract concepts such as symmetry can be learnt implicitly.

The role of learning in shaping agency and awareness. Here, rather than exploring the role that awareness plays in learning, we turn to exploring the role that learning plays in consciousness. **WP6**, led by **INT1** (UCLondon—Haggard) in collaboration with **P1** (ULB—Cleeremans) and **P3** (UG—Brass) examines the relation between the conscious sense of agency, and the acquisition of instrumental knowledge. Among the outstanding questions asked are: how does the prospective sense of agency arising during action selection relate to previous instrumental learning of action-outcome relations? What level of instrumental learning is required to support sense of agency, and how do brain networks for conscious agency interact with those for instrumental learning? **WP7**, led by **P1** (ULB—Cleeremans) in collaboration with **P3** (UG—Brass), **P5** (UCL—Rossion), **INT1** (UCLondon—Haggard) and **INT2** (USussex—Dienes), will explore, both through behavioural experiments and through computational modelling, the extent to which training modulates perceptual experience by manipulating either bottom-up factors such as properties of the stimulus and the duration of training or by manipulating top-down factors such as the existence of appropriate systems of metarepresentations. Further studies will explore how neurofeedback methods can modify conscious experience.

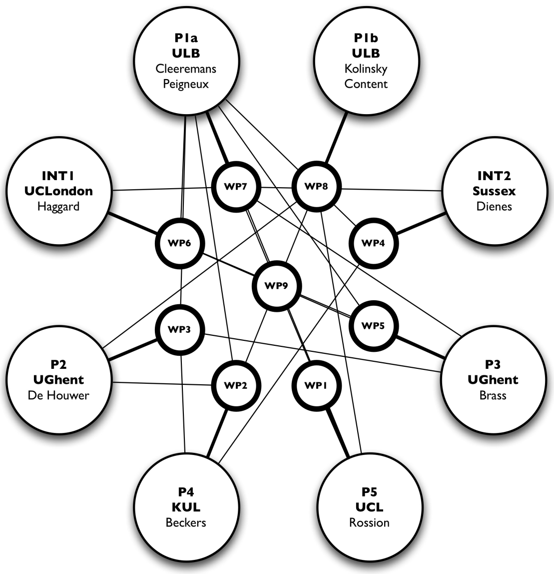
References are listed at the end of Form D.

FORM D: DETAILED DESCRIPTION OF THE PROPOSAL

1. Introduction

Here, we present the different studies that we propose to carry out so as to address the objectives of the project. The project as whole is structured in nine Work Packages (WP).

WPs 1-8 constitute the bulk of the planned scientific work; while **WP9** is a management WP. Each WP is placed under the responsibility of a Lead Partner who will collaborate with associated teams to develop the proposed research. Most WPs involve three or more partners. Figure **F1.1** illustrates how the different partners will interact over the course of the project. The figure makes it clear that the project will foster numerous interactions between the partners. Each partner is involved, on average, in three different WPs, and in turn, each WP leverages the expertise of several partners. Such interaction and integration is instrumental to the success of the project, as some partners have specific expertise (i.e., sophisticated behavioural methods to assess awareness; access to brain imaging facilities; expertise in specific methods through which to analyse fMRI data; access to an animal lab) that is necessary for other partners to carry out the proposed research.



F1.1: An illustration of the interactions that will be fostered by the project. Each of nine Work Packages is under the responsibility of a Lead Partner. Each participating team is involved in different work packages.

In the following, we first describe the methods (Section 2) we will use. Next, in Section 3, we describe each WP in turn. Their presentation is organized to reflect, roughly, a hierarchy of information processing, beginning with the most basic phenomena (e.g. perceptual learning, memory consolidation and sleep, animal learning), continuing with implicit learning , volition, and consciousness, all the way to high-level learning such as that involved in literacy.

The nine WPs are summarized below:

WP1: Mechanisms and dynamics of learning and consolidation of novel visual patterns (faces). Lead Partner: P5 (UCL - Rossion). Associated teams: P1 (ULB –Cleeremans & Peigneux).

WP2: Mechanisms of conditioning and causal learning. Lead Partner: P4 (KUL – Beckers). Associated teams: P2 (UG – De Houwer) & P1 (P1a: ULB – Cleeremans & Peigneux; P1b: Kolinsky).

WP3: Mechanisms of learning via instructions. Lead Partner: P2 (UG – De Houwer). Associated teams: P1 (ULB – Cleeremans), P3 (UG – Brass) & P4 (KUL – Beckers).

WP4: Mechanisms of implicit learning. Lead Partner: INT2 (Sussex – Dienes). Associated teams: P1 (ULB – Cleeremans) & P4 (KUL — Beckers).

WP5: Mechanisms of human decision making. Lead Partner: P3 (UG – Brass). Associated teams: P1 (ULB – Cleeremans & Peigneux) & INT1 (UCL – Haggard).

WP6: Mechanisms of instrumental learning and the conscious sense of agency. Lead partner: INT1 (UCLondon – Haggard). Associated teams: P1 (ULB – Cleeremans) & P3 (UG – Brass)

WP7: Mechanisms of awareness: Learning to be conscious. Lead Partner: P1 (ULB – Cleeremans). Associated teams: P3 (UG – Brass), P5 (UCL – Rossion), INT1 (UCLondon – Haggard) & INT2 (Sussex – Dienes)

WP8: Mechanisms of cultural learning. Lead Partner: P1 (ULB – Kolinsky & Content). Associated teams: P5 (UCL – Rossion) & P2 (UG – De Houwer)

WP9: Project management. Lead Partner: P1 (ULB – Cleeremans)

2. Methods

COOL leverages a wide variety of methods typical of cognitive science. The bulk of the proposed studies involves behavioural experimentation, using methods typical of cognitive psychology (e.g., mental chronometry, eye tracking, electroencephalography). Because the project is focused on the dynamics of learning, whenever relevant, single-trial electromyography[20], a novel method that **P1** (ULB—Cleeremans) is developing, will be used to track subthreshold motor activity in the muscles of the responding hands to analyse choice dynamics in real-time. We will also leverage a novel method for the presentation of subliminal material: Gaze-contingent stimulation[21,22], which, unlike traditional masking methods, makes it possible to present stimuli for periods extending up to seconds while ensuring they remain simultaneously strong and invisible.

Further, as most of the studies proposed in COOL are aimed at exploring patterns of associations and dissociations between different aspects of processing, we will strive to collect, whenever possible, measures of performance, measures of awareness, measures of metacognitive access, and measures of cognitive control concurrently and on every trial so as to be able to track their respective dynamics. Thus, depending on the specific paradigm, we will use different combinations of (1) objective measures such as the Signal Detection Theory (SDT) [81-83] measure of sensitivity d', subjective measures of awareness such as the Perceptual Awareness Scale (PAS)[23,24], metacognitive measures such as confidence judgments[25] post-decision wagering[26], and Type II d'[27] and measures of cognitive control such as Jacoby's inclusion-exclusion methodology (the process dissociation procedure[28] that we successfully pioneered the use of in implicit learning research[29].

Neuroimaging methods (fMRI) methods and electromagnetic recordings (high-density EEG, MEG) will also be used in order to identify and characterize the neuro-functional correlates of unconscious and conscious learning processes, as well as the temporal dynamics of these processes. Computational modelling methods will be used to test and generate hypotheses about the behaviour of the human leaning system(s by means of computational modelling methods, principally neural networks.

The proposed studies will include as many participants as needed to achieve sufficient power to detect small differences[30] (typically about 24 participants). However, we will also rely on larger samples of participants when assessing learning abilities of a given function in the normal population, perform psychophysical studies with fewer participants tested for a large amount of trials, and single-case neuropsychological studies. Finally, some WPs also involve research on animals and will thus involve behavioural and neurobiological techniques and methods from the animal behavioural neuroscience field. Most of the behavioural studies in rats will make use of a conditioned emotional suppression procedure, in which cue-elicited interference with on-going instrumental responding is taken as an index of successful fear learning about that cue. These behavioural procedures will be supplemented by selective neurotoxic (lesioning) or pharmacological interventions to probe their neurobiological underpinnings.

3. WP Description

The proposal is organized in nine interacting WPs, all relevant to the central goal of the project to contribute to our understanding of the relationships between conscious and unconscious learning.

In **WP1**, **P5** (UCL—Rossion) and **P1** (ULB—Peigneux) (ULB) will collaborate to explore the neuro-functional mechanisms of conscious and unconscious memory acquisition, as well as post-training consolidation for novel faces.

In **WP2**, **P4** (KUL—Beckers), **P2** (UG—De Houwer) and **P1** (ULB—Cleeremans, Peigneux & Kolinsky) will pursue the idea that seemingly basic associative learning phenomena may reflect sophisticated causal inference skills in animals. In another series of studies, the same teams will pursue recent developmental studies that suggest that the development of causal learning goes hand in hand with the development of particular inferential reasoning and working memory abilities that are important for human causal learning according to a propositional approach to associative learning.

WP3, carried out by **P2** (UG—De Houwer) in collaboration with **P1** (ULB—Cleeremans), **P3** (UG—Brass) and **P4** (KUL—Beckers), will explore the properties of conditioning and habituation via verbal instructions.

WP4 led by **INT2** (USussex—Dienes) in collaboration with **P1** (ULB—Cleeremans) and **P4** (KUL—Beckers), will explore (1) whether learning can take place with subliminal stimuli, and (2) whether abstract concepts such as symmetry can be learnt implicitly.

WP5, led by **P3** (UG—Brass), in collaboration with **P1** (ULB—Cleeremans) and **INT1** (UCLondon—Haggard), explores the respective influence of conscious and unconscious learning processes on decision making, leveraging recent pattern classification of fMRI data (MPVA) to quantify the influence of unconscious sources.

WP6 and **WP7**, rather than asking how consciousness shapes what one can learn, are instead dedicated to exploring how learning shapes conscious experience. **WP6**, led by **INT1** (UCLondon—Haggard) in collaboration with **P1** (ULB—Cleeremans) and **P3** (UG—Brass) examines the relation between the conscious sense of agency, and the acquisition of instrumental knowledge. Among the outstanding questions asked are: how does the prospective sense of agency arising during action selection relate to previous instrumental learning of action-outcome relations? What level of instrumental learning is required to support sense of agency, and how do brain networks for conscious agency interact with those for instrumental learning?

WP7, led by **P1** (ULB—Cleeremans) in collaboration with **P3** (UG—Brass), **P5** (UCL—Rossion), **INT1** (UCLondon—Haggard) and **INT2** (USussex—Dienes), will explore, both through behavioural experiments and through computational modelling, the extent to which training modulates perceptual experience by manipulating either bottom-up factors such as properties of the stimulus and the duration of training or by manipulating top-down factors such as the existence of appropriate systems of metarepresentations (using hypnosis, for instance). Further studies will explore how neurofeedback methods can modify conscious experience.

Finally, **WP8**, lead by **P1** (ULB—Kolinsky) in collaboration with **P5** (UCL—Rossion) and **P2** (UG—De Houwer), is dedicated to the feedback effects from newly acquired, cultural knowledge such as reading and writing (a "secondary ability") on the phylogenetically and ontogenetically older biological system of spoken language and nonlinguistic vision.

WP1 — Mechanisms and dynamics of learning and consolidation of novel visual patterns (faces)

Lead Partner: P5 (UCL – Rossion)
Associated teams: P1 (ULB – Peigneux & Cleeremans)

The main objective of **WP1** is to explore the cognitive and neural mechanisms of memory acquisition and post-training consolidation for novel faces. Although faces are complex visual patterns, they are learned effortlessly, throughout life, and can be taken to constitute an excellent domain for studying elementary and fundamental mechanisms of learning in humans.

The human face conveys and reveals a wide variety of critical information about an individual (e.g., identity, sex, mood). Distinguishing individual faces, in particular, requires elaborate and refined perceptual skills called for by few other categories of objects, so that the face is a fantastic stimulus to study perceptual learning[31]. Adults attain a high degree of proficiency with these skills, as evidenced by the fact that identifying a person requires less than a second[32] despite the high similarity among different faces. They are very few — if any — stimuli in the environment that we are exposed to so frequently and learn as much, and as well, as faces. Learning of faces involves no formal training and proceeds quasi automatically during all of our life. However, surprisingly, while there is substantial research devoted to understanding how humans *perceive* faces (see Calder et al.[33]), the factors and dynamics that subtend the creation of novel face representations in the human brain have been scarcely studied. **WP1** will take advantage of the joint expertise of **P5** (UCL - Rossion) in face perception and of **P1** (ULB — Peigneux) in the mechanisms of learning and memory to explore the neuro-functional mechanisms of memory acquisition and post-training consolidation for novel faces. **WP1** contains six interconnected research lines, described hereafter.

WP1a: behavioral characterization of the gradual installation of novel face representations. A first objective will be to characterize human performance at explicit (i.e., with intention to do so and full awareness) face recognition and learning, something that is unfortunately still missing or available only through recent web-based surveys [34]. This will help us define how accurate short-term and long-term face memory is, and how variable it is in the human population. We will collect data on face learning and recognition performance from a large sample, from 18 years of age (the age at which the face perception system is supposed to be mature) to 65 years of age.

Participants will explicitly encode a large set of full-view faces, and their learning curve and subsequent recognition performance (old/new discrimination among several distractors) will be characterized individually. The same experiment will be carried out with control stimuli (multi-parts novel shapes) that can be perceptually distinguished based on clear shape, texture and color attributes. Both short-term and longer term memory for faces (i.e. after consolidation during at least one night of sleep) will be assessed. Then, in participants aged 18-25 years, we will determine which factors are important in learning new faces. Factors that will be manipulated include factors *intrinsic* to the domain: learning and recognition of atypical *vs.* typical faces[35]; faces presented in multiple or single orientations at encoding; faces encoded as static patterns or as dynamic movies[36] as well as *extrinsic* factors: Association of the face with a visual scene context, or with affective values. We will also test the hypothesis that faces can be learned better if, at encoding, they are presented dynamically, just like they are supposed to be perceived (i.e., from low to high spatial frequencies rather than the opposite, see Morrison & Schyns[37]; or from parts to whole rather than whole to parts, see Jiang et al.[38]. An important aspect of this project is that a subset of the (young) participants will be tested longitudinally, at longer intervals (e.g. 1-year interval), testing memory for faces learned during the first episode.

WP1b: Neural correlates of the installation of novel face representations. Many areas devoted to face perception have been disclosed in the human brain using fMRI, particularly in the right ventral occipito-temporal cortex. Several areas are also activated in response to simple exposure to faces in the medio-temporal and prefrontal cortices[39,40]. One outstanding question is whether learning new faces modulates the activity of the occipito-temporal areas specifically involved in face *perception,* or if there is a clear dividing line between these areas and the face memory systems located in more anterior structures. Studies testing face familiarity in the face-responsive regions of the ventral extrastriate cortex have reported largely inconsistent results[41,42], most likely due to stimuli and task confounds. We will avoid such confounds by using large sets of faces learned visually only, comparing familiar and unfamiliar representations in orthogonal (i.e., not memory-based) tasks. To maximize the chances to elicit changes in neural representations of newly learned faces, the faces will be learned extensively, during at least two days before fMRI testing, using multiple views. They will then be presented as individual trials in slow event-related paradigms in the form of dynamic sequences gradually revealing face identity (see Jiang[38], for 20s face detection sequences). This slow mode of presentation removes the large activation associated with the sudden onset (flash) of a face from the response of interest and provides an excellent signal-to-noise ratio with a few trials, also allowing testing for time-onset differences between areas discriminating novel from learned faces. Another outstanding question is whether anterior temporal and medial temporal regions (e.g., enthorinal cortex, amygdala) play a *general* role in learning and long-term memory retrieval or if some of these regions are also specifically involved in face learning as compared to learning of other complex visual patterns? Here, this hypothesis will be tested specifically by comparing the learning of faces to our set of complex 3D shape objects, which can be also morphed to a single shape and gradually revealed.

WP1c Mechanisms and dynamics of face learning at the neural level. In this work package we will test *how* learning affects the perceptual representation of faces[43-45]. There is evidence that face learning entails improvements in perceptual discrimination of individual faces[46], and generalization across different pictures for learned faces[47]. Consequently, repetition suppression (RS) effects in neuroimaging[48] to the consecutive presentation of similar (morphed) faces should be reduced when they are learned as different facial identities. Moreover, multivariate pattern analyses (MVPA) should reveal increases in neural pattern separation with such learning. In contrast, different pictures of a given individual should be initially associated with little RS and with distinct patterns of activity. Learning of the different views of that individual should increase RS and decrease the difference between neural patterns. These hypotheses will be tested by means of the slow revealing face paradigm described above. Then, we will explore the phenomenon that different faces can be merged into a single representation if they are presented in a gradual order[49,50]. We will test directly whether this mechanism can be applied to our ability to update and maintain a continuously updated memory representation of faces across age, and thus recognize faces all along our life. Artificially older faces (morphed with average older faces) will become gradually associated and merged with initially learned younger faces. The neural correlates of this effect will also be studied with repetition suppression and MVPA in neuroimaging.

WP1d Effect of removal of typical face interference at learning unexperienced face categories. Using an original approach, we will investigate how constant exposure to face stimuli in real life makes it difficult to evidence marked learning effects for this very ecological material. To do so, groups of participants will learn novel faces in a controlled, constant environment in which all other face sources will be removed (i.e., masked experimenter, no mirror, etc.) or carefully manipulated (experimental stimulation) before further testing. To do so, we will take advantage of sleep-monitoring EEG experiments led by **P1** (ULB — Peigneux), in which participants can be kept isolated for an extended period of time. Two aspects will be tested in particular. First, we will test whether learning of faces from another "race" (e.g., Asian faces in Caucasian participants[51], and inverted faces can improve if participants are not exposed to potentially competing stimulation of same-race upright faces between learning and test. Finally, we will define how the face-space representation of learned faces can be preserved without, or experimentally modified with, interfering face experience in between learning and test. These studies should reveal the critical role of constant experience in updating and interfering with our face memory representations.

WP1e Consolidation processes across sleep and wakefulness. Here, we will test how and whether post-training offline consolidation processes across sleep and wakefulness contribute to the strengthening of newly learned face representations, making these more resistant to further interference, an effect consistently observed in the declarative memory domain (for a review see e.g. Peigneux and Smith[52]). The few prior studies using face material have led to inconsistent results, suggesting either no effect[53] or a moderate effect[54,55] of post-training sleep and especially REM sleep[56] for consolidation. Besides tasks and stimuli differences, these studies have not controlled for potential interferences on consolidation due to continuous exposure to other faces than the learned material between learning and testing sessions, as explained in **WP1d**. Here, we will investigate sleep-dependent consolidation effects in controlled, interference-free conditions, by comparing performance across sleep periods early in the night, dominated by slow wave sleep (SWS), and late in the night, where rapid eye movement (REM) sleep prevails, as well as across corresponding nocturnal intervals of wakefulness. This will thus additionally control for possible circadian effects on performance[57]. In a first experiment, participants will learn novel inverted faces and then be prevented from visual exposure to any other face material in the controlled environment of the sleep laboratory (no mirror, masked experimenter) during the retention period. Providing an effect of post-training sleep is evidenced, we will then conduct further experiments to determine which components of face exposure interfere with the acquisition and sleep-dependent consolidation of novel faces.

WP1f Incidental learning of faces. A subset of the studies described above will be performed with faces learned *incidentally*, that is through face perceptual tasks at encoding (gender categorization, face matching, etc.) rather than through explicit instructions to encode the faces. While incidental learning of faces should lead to overall lower recognition performance (due to reduced attention) than explicit learning, a core hypothesis of the project is that incidental learning is closer to the natural way in which faces are encoded. Therefore, it should lead to more holistic (vs. part-based) representations[58], and call upon neural structures more specialized for faces than when learning is explicit and fully conscious. Individual differences in the human ability to recognize faces should also be revealed better with incidental rather than explicit learning. Unconscious learning of faces – presented for long durations through gaze contingency crowding[21] – will also be tested through collaboration with **P1** (ULB — Peigneux & Cleeremans).

Altogether, the studies performed in this work package should contribute significantly to our understanding of the neuro-functional correlates of face encoding in memory. It will also provide normative data of human face learning abilities, so that frequent complains at face memory difficulties in clinical neuropsychology (posterior brain damage, Mild Cognitive Impairment as a sign of pre-dementia, semantic dementia, etc.), can be better evaluated.

WP2 — Mechanisms of conditioning and causal learning

Lead Partner: P4 (KUL – Beckers)
Associated teams: P2 (UG – De Houwer), **P1** (ULB – P1a: Cleeremans & Peigneux, P1b: Kolinsky)

The general goal of **WP2** is to contribute to our understanding of the processes that govern seemingly basic associative learning phenomena in animals and in developing and adult humans.

Animal learning research has often been inspired by a desire to trace elementary learning processes in a pure form, uncontaminated by humans' ability for deliberate thought and analytical reasoning. The implicit assumption in much of this research tradition is that the performance of animals, lacking complex language and consciousness, demonstrates how far a cognitive system can get without the capacity for symbolic, conscious thought. Similarly, developmental studies on causal learning in children often assume that causal learning performance in pre-school children must reflect a pre-causal stage of cognitive functioning, as such children would lack true insight into cause-effect mechanisms. Again then, performance in these children should reflect a more fundamental level of low-level association formation.

Here, in the first two proposed lines of research, we will challenge these fundamental assumptions with respect to both animal conditioning and children's causal learning. In two further lines of research, we will investigate the inverse claim that under some circumstances, conditioning can take place without awareness in the complete absence of awareness in adult humans, — an even more controversial topic.

WP2a: Animal conditioning as active inference-making. Recent findings suggest that some basic animal learning phenomena that are typically attributed to the operation of hard-wired associative principles may be better conceived of as indicative of active inference-making on the part of the animal rather than passive association formation and retrieval (e.g., Beckers et al.[59]; Blaisdell et al.[60]). One of these phenomena is blocking. Suppose an animal first learns that a particular cue A is consistently followed by an aversive outcome (A+ training), and then learns that the simultaneous presentation of that cue A with a second cue, X, is also followed by that same outcome (AX+ training). A typical result of such training is that cue X, when presented alone, elicits very little conditioned fear (much less than when AX+ training had not been preceded by A+ training; Kamin[61]). Associative learning models typically explain this as due to selective learning (animals fail to learn about X, e.g., because the outcome on AX+ trials is non-surprising; Rescorla & Wagner[62]) or to selective memory retrieval (the activation of an X-outcome associative link is outdone by activation of the stronger A-outcome link; e.g., Miller & Matzel [63]). However, previous collaborative work by **P4** (KUL — Beckers) and **P2** (UG — De Houwer) has demonstrated that blocking may instead be the result of flexible inference-making, a finding that is hard to reconcile with associative positions. More specifically, they demonstrated that changing animals' assumptions about the additivity of causal influence (by training them on a non-linear causal problem) diminished the degree of blocking resulting from subsequent A+ / AX+ training[59,64]. This suggests that blocking is the result of an inference that relies on an assumption of linear causal integration[65].

These results mirror findings in human causal learning (e.g., Beckers et al.[66]), where the evidence for the involvement of non-associative processes in learning is now overwhelming[67]. Still, claims have been made that the animal data presented above could be accounted for in associative terms[68]. In a series of experiments, we will present further tests of the idea that animal conditioning partly reflects non-associative inference-making, as well as direct tests of predictions that can be derived from an associative account of our previous results.

A first series of experiments will revisit the sensitivity of blocking to training of non-linearity. Our previous experiments involved training of animals on non-linearity before performing the actual blocking training and test. However, from an inferential point of view, it should be equally possible to modulate the inference that animals make on a blocking task by training them on non-linearity after the facts, that is, after, rather than before the actual blocking training. Such inferential flexibility is not expected from an associative perspective on learning and would be incompatible with Haselgrove[68]'s associative account of our previous findings.

A second series of experiments will focus on a different form of non-linearity (positive and negative patterning), and its influence on causal inference from compound stimuli to their constituent elements and vice versa. Human causal learning research has demonstrated that once people master patterning problems, they will generalize the underlying patterning rules to novel sets of stimuli[69]. While there is evidence to suggest that rats can learn to solve patterning problems too [70], it is unclear whether they would generalize the underlying XOR rule to novel sets of stimuli. Associative and connectionist models suggest that they would not, whereas an inferential perspective predicts that under certain circumstances, they would [70].

Further work in this line of research will investigate specific predictions derived from an associative account of our previous data[68]. Although this account fails to provide a full explanation of all findings, it does make a few interesting predictions, e.g., concerning the extent of generalized responding after non-linearity training and the effect of a context shift between training and final test on conditioned responding. Simultaneously, we plan to probe the neurobiological substrate of effects of non-linear training on subsequent conditioning. In particular, we intend to investigate, through lesion studies, the involvement of a cortico-striatal, dopamine-based system that has been implicated in top-down, rule-based control over acquired responding through prefrontal influence of striatal processing (see Cools[71]).

WP2b: Developmental aspects of causal learning. In a line of research complementary to the animal work described above, **P4** (KUL — Beckers) in collaboration with Teresa McCormack (Queen's University, Belfast, UK) has explored the developmental corollaries of children's causal learning competence. One distinctive benefit of taking a developmental approach to these issues is that we can identify an age range at which there are marked individual differences in cue competition effects, with some children showing these effects and others not. We can then examine whether particular types of cognitive processes need to be developmentally intact for cue competition effects to be observed, by measuring such processes in our population of children and by looking for relationships with cue competition effects. Thus, individual differences studies with children provide us with a unique opportunity to examine if particular higher-level cognitive processes are in fact necessary for this type of causal learning.

Initial work revealed interesting relationships between cognitive abilities and the cue competition effect of blocking. We found individual differences in this effect between 3 and 6 years, with older children being more likely to show blocking. Moreover, only children who exhibited specific inferential reasoning abilities showed blocking; blocking was also significantly correlated with children's working memory abilities. Taken together, these findings provide important initial evidence that effortful reasoning processes that place demands on working memory are involved in blocking[72].

P4 (KUL — Beckers and **P2** (UG — De Houwer) will examine in greater detail the nature of the effortful reasoning processes that may underpin blocking in humans. Some recent characterizations of such processes[72,73] suggest that they may involve not just inferential reasoning, but reasoning with a specifically counterfactual component. The basic suggestion is that in such tasks, to perform well participants should not just passively register the patterns of evidence presented to them, but should actively consider what would or could have been observed if the status of cues had been different. The suggestion that blocking involves counterfactual reasoning gains some support from another initial study conducted by Beckers with McCormack that shows that encouraging children to think counterfactually selectively facilitates blocking.

The proposed research will build on the fact that the age range at which blocking appears to emerge in causal learning tasks is also the age range at which inferential reasoning and counterfactual thinking abilities are developing. It is also an age at which there are marked changes in effortful cognitive processes, as demonstrated by numerous studies of the development of executive processes in this age range [74]. Moreover, recent developmental evidence suggests that the development of counterfactual reasoning may itself be linked to the developmental improvements in executive functions [75]. In a large-scale individual differences study of children aged 3-6 years, a battery of measures will be administered. First, cue competition effects will be assessed. Children will also complete a set of verbal counterfactual reasoning tasks known to show individual differences in this age range [75]. A battery of executive tasks appropriate to this age range will also be administered, including those known to correlate with reasoning in children. These will include tasks measuring inhibition and working memory [76]. General ability (verbal intelligence and non-verbal ability) will be measured using sub-tests from the WIPPSI-III battery, which is suitable for this age group. Statistical analyses will focus on what cognitive abilities predict children's causal learning, and in particular the cue competition effect of blocking.

Follow-up studies will then focus on possible discrepancies in performance when causal learning is probed using deliberate, controlled measures (yes/no answers or choice performance) versus when using more impulsive, less consciously-controlled measues of learning. If training on non-linear problems would somehow change subsequent associative processing (as some authors have argued, e.g., Livesey & Boakes[77]), one would expect that effects of such training on blocking be observed in highly controlled (e.g., verbal) as well as more automatic (e.g., performance-based) behavioural indices of learning. From the idea that training on non-linear problems affects blocking via inferential reasoning, however, one would expect that such modulation of blocking (and blocking in general) appears much weaker in implicit measures of learning than in explicit ones (yes/no or choice). In this line of work, the contribution of **P1** (ULB — Cleeremans) and **P2** (UG — De Houwer) will be most valuable, given their established expertise in the use of implicit measures of learning (e.g., Cleeremans et al.[78]; De Houwer et al. [79]). We will also consider extending some of the proposed studies to infants, using **P1** (ULB — Cleeremans)'s newly set up babylab. Finally, as it has been argued that changes in memory, executive functions and reasoning abilities are also related to literacy, more precisely to the access to multiple memory codes and to the need to manage them[80], we will control for this by examining illiterate adults, compared to literates and «ex-illiterates» who only learned to read at adult age. The expertise of **P1** (ULB— Kolinsky) in studies of the cognitive consequences of literacy will help in this matter.

WP2c: Learning novel associations outside awareness during sleep. As indicated, the question of whether animal conditioning and causal learning in young children might be driven in whole or in part by active inference-making rather than by automatic association formation is a topic of considerable controversy. Equally controversial is the extent to which the human brain can learn novel information at all in the absence of consciousness or awareness. In this respect, the creation of novel associations during controlled states of sleep that would manifest themselves in behavioural and/or neurophysiological changes in subsequent wake states, would be a conclusive demonstration of unconscious learning abilities. Up to now there is some evidence that conditioned cardiac rhythm responses acquired during wakefulness can be elicited during subsequent sleep in man[81,82] and animal (e.g. Maho and Hennevin[83]), but evidence for the creation of novel associations during sleep that can be elicited in a subsequent wake state remains scarce and inconclusive[84], although animal data have been more convincing (e.g. Maho and Bloch[85]; for a review see Hennevin[86]). In **WP2c**, carried out in collaboration with **P1** (ULB — Peigneux) and **P2** (UG — Beckers), we will probe this hypothesis both in man and animal using two main lines of research. On the one hand, we will perform sensory preconditioning during sleep, systematically pairing two stimuli (A, B) from different modalities. During subsequent wakefulness, preconditioned stimulus B will be associated with an aversive US (air puff) in a classical eyeblink-conditioning procedure. If A and B have been successfully associated during sleep, stimulus A (not presented during the conditioning procedure) should elicit a similar conditioned eyeblink response as B. On the other hand, we will perform studies comparing trace and delayed conditioning of autonomic responses directly during sleep, to determine to what extent trace conditioning is possible during unconscious sleeping conditions.

WP3 — Mechanisms of Learning via instructions

Lead Partner: P2 (UG – De Houwer)
Associated teams: P1 (ULB – Cleeremans), **P3** (UG – Brass) and **P4** (KUL – Beckers)

Traditional associative learning research focused primarily on low-level associative processes that are assumed to operate in both human and non-human animals. In fact, many prominent learning theories (e.g., Rescorla & Wagner[62]) were developed primarily on the basis of research in animals but are assumed to hold also for humans. As such, associative learning as a phenomenon (i.e., change in behavior as the result of relations between events in the world) was confounded with association formation as an underlying mechanism. In line with the overall aims of our project, in this WP we explore the merits of dissociating these two aspects of learning research. Inspiration for this line of research comes from so-called propositional models of learning that focus on the role of high-level propositional processes in learning (e.g., Mitchell et al. [6]). The impact of these processes can be examined in its most pure form in studies on learning via instructions (see Lovibond[73]). For instance, after instructing participants about the fact that a light will be followed by an aversive shock, the light will evoke a conditioned response even when the light has never actually been followed by a shock[87]. Although instructed conditioning effects are known to occur, they have not been investigated systematically, probably because they do not fit well with the low-level process models that dominated learning research for the past 100 years. Within this WP, we engage in such a systematic study of associative learning via instruction, both at the behavioral and neural level. Moreover, for the first time ever, this research is extended to non-associative forms of learning.

WP3 will benefit from the expertise of different partners. **P2** (UG — De Houwer) will contribute his expertise on the involvement of high-level propositional processes in different types of learning (see De Houwer, 2009; Mitchell et al., 2009). Both **P3** (UG — Brass) and **P2** (UG — De Houwer) have already published studies on learning via instruction (e.g., De Houwer et al. [88,89] and will use this project to intensify their collaboration. Moreover, **P3** (UG — Brass) adds his expertise on brain imaging techniques and the impact of high-level cognitive processes on low-level brain activity (e.g., Harstra et al., 2011). **P4** (KUL — Beckers) and **P2** (UG — De Houwer) have collaborated in the past on demonstrating the impact of high-level propositional processes on learning (e.g., De Houwer et al. [90]). Their expertise in studying the functional properties in learning provides a strong basis for comparing the functional properties of learning via instructions and experience. Finally, **P1** (ULB — Cleeremans) has conducted research that pitted experience and high-level knowledge against each other (the Perruchet effect; e.g., Destrebecqz et al. [91]). He can help identify conditions under which experience and instruction might dissociate.

WP3a: Functional and neural properties of associative learning via instruction. The functional properties of learning refer to the conditions under which learning occurs, that is, under which a regularity in the environment (e.g., the fact that a light always precedes the delivery of a shock) leads to a change in behavior (e.g., an increase in skin conductance upon presentation of the light). We examine the functional properties of both instructed fear conditioning (i.e., conditioned changes in fear responses) and instructed evaluative conditioning (i.e., conditioned changes in liking). We focus on these types of learning because they are often seen as typical examples of learning that are mediated by low-level association formation processes[92]. As such, we test the limits of the idea that associative learning in general is mediated by higher-order propositional processes[6,73]. For each type of learning, we examine key functional properties that have proven to be crucial in the development of learning theories (e.g., selectivity in learning, degree of statistical contingency, cue competition, US-revaluation). In all studies, we compare learning when participants actually experience the stimuli and when they are merely instructed about the relation between the stimuli. By directly comparing learning via instructions and learning via experience, we can uncover for the first time quantitative and qualitative differences between these two types of learning. If learning via instructions has the same functional properties as learning via experience, this would support the idea that the same mental processes mediate both types of learning. Given that learning via instructions is the prototypical example of learning that is due to higher-order propositional processes, observing parallels between learning via instructions and experience would support the idea that also learning via experience is mediated by higher-order propositional processes (see also Lovibond[73]). Importantly, when differences are observed, one can look for ways to reduce these differences (e.g., by asking participants to engage in mental imagery during the instructions). As such, our research can provide a means for optimizing learning via instruction.

Due to space limitations, we cannot discuss each of the studies that will be conducted. Instead, we provide a number of examples. In a first series of studies, participants receive specific information about the number of co-occurrences of a neutral symbol and a shock, as well as the number of events in which only the symbol or shock is present or neither is present. We examine whether conditioned changes in skin conductance responses to the symbol vary as a function of the degree of statistical contingency between the symbol and the shock and whether they do so in the same way as learning via experience (e.g., whether co-occurrences carry more weight than events in which both stimuli are absent). We also examine the role of contingency in evaluative conditioning (e.g., conditioned changes in the liking of the symbol). This is particularly interesting because there are indications that, compared to fear conditioning, evaluative conditioning depends more on stimulus co-occurrences than on statistical contingency. If we can replicate this difference when participants receive only verbal information about the stimulus relations, it would suggest that fear conditioning and evaluative conditioning can be dissociated even when both are based on higher-order propositional processes. This would provide an important proof of the principle that a single propositional learning process can result in dissociations between different types of conditioned changes in behavior. Note that to circumvent demand effects, changes in liking will be assessed with implicit measures[93]. In a second series of studies, we examine cue competition effects in fear conditioning. Until now, evidence concerning this issue is limited to one demonstration of one specific cue competition effect (i.e., retrospective revaluations[73]). We examine also other, less complex cue competition phenomena (e.g., overshadowing, forward blocking) and directly compare these phenomena in learning via instructions and via experience. Furthermore, we test for the first time whether cue competition effects can be obtained in instructed evaluative conditioning. There is some indication that evaluative conditioning with experienced stimulus relations is less susceptible to cue competition effects fear conditioning[94]. Hence, this line of studies could again lead to a dissociation between two types of learning via instruction. In a third series of studies, participants are told either that pictures of spiders will be followed by a shock or that pictures of flowers will be followed by a shock. Earlier studies in which such stimuli were actually presented showed that experiencing the spider-shock relation leads to larger conditioning effects than experiencing the flower-shock relation. Moreover, the effect of the spider-shock relation tends to be more resistant to extinction[95]. We examine whether learning via instructions is selective in a similar manner, both with regard to acquisition and extinction. Because such selectivity effects in learning are typically attributed to primitive, hard-wired processes[96], it would be particularly informative if these effects can be obtained without experiencing the paired stimuli. In a fourth series of studies, we examine similarities and differences in the neural correlates of fear conditioning via experience and via instructions. Although much is known about the brain regions that are involved in fear conditioning via experience, very few studies have examined this for fear conditioning via instructions (for an overview see Mechias et al. [97]). To this end, we will replicate influential fMRI studies on fear conditioning via experience (see Phelps & Ledoux[98]) but replace the actual pairing of the stimuli with instructions about how the stimuli are related. Previous work on instructed fear conditioning has primarily focused on the question whether brain activation of the CS+ differs between an instructed and an experienced condition. This research indicated that the rostral cingulate zone (RCZ) shows consistent activity for the CS+ while the amygdala was not consistently activated[97]. Our research will primarily focus on the brain mechanisms that are involved in the implementation of verbal instructions. In other words, we will investigate which brain areas modulate brain activation in the RCZ and amygdala in the instructed condition. From our work on verbal instructions in the action domain we predict the posterior fronto-lateral cortex to be involved[99].

WP3b: Functional and neural properties of non-associative learning via instruction. Until now, research on learning via instruction has been limited to associative learning, that is, to changes in behavior that are due to relations between events. We will examine for the first time non-associative learning via instruction. Non-associative learning refers to a change in behavior that is due to regularities in the presentation of a single stimulus. For instance, a stimulus that is repeatedly presented will evoke a smaller orientation response than a stimulus that is presented only once[100]. This change in behavior can be attributed to a regularity in the frequency with which a stimulus appears. We examine whether verbal information about such regularities also leads to changes in behavior. In a first series of experiments, participants see several movies in which objects are presented one after the other. Different objects are presented in different movies. Before each movie, participants are shown some of the objects they will see in that movie together with information about how often that object occurs. They are simply asked to watch the movies while physiological orientation responses are measured.

We predict that the first presentation of a stimulus that is said to occur often in a movie will evoke less intense orientation responses than the first presentation of a stimulus that is said to occur infrequently. In a second series of experiments, changes in reaction time performance are measured rather than changes in orientation responses. During an oddball task, participants are asked to respond with a right keypress response to the presentation of a target picture (e.g., the picture of a flower) and with a left keypress response to other stimuli. The target appears on only 5% of all trials. A non-pictorial distractor (e.g., #) appears on 88% of all trials, a first pictorial distractor appears on 5% of the trials, and a second pictorial distractor appears on 2% of the trials. Participants are shown the frequent and infrequent pictorial distractor at the start of each series of trials and are told that the first appears more often than the latter. Given that novel distractor stimuli lead to slower responses than repeated distractor stimuli (i.e., habituation of the oddball response), we predict that the instructed infrequent distractor evokes slower responses than the instructed frequent distractor. In both series of experiments, we examine whether the properties of habituation via instruction mirror those of habituation via experience (e.g., whether dishabituation occurs for instructed frequent stimuli). In a third series of studies, we examine neural adaptation via instruction. Repeatedly presenting a stimulus is known to reduce the averaged neural activity that is evoked by that stimulus[101,102]. In line with the other two lines of studies, we inform people about whether a particular stimulus will be presented often. We anticipate that instructed infrequent stimuli will evoke more neural activity than instructed frequent stimuli. Here brain imaging will help us to determine whether instructions lead to adaptation on the representational level (e.g. in the visual cortex) or to changes in attentional processes (i.e. in frontal and parietal cortex).

WP4 — Mechanisms of implicit learning

Lead Partner: **INT2** (Sussex – Dienes)

Associated teams: **P1** (ULB – Cleeremans) and **P4** (KUL — Beckers)

WP4 develops one of the proposal's main goal of understanding the limits of unconscious learning. Specifically, its two objectives are (1) to determine if the development of unconscious structural knowledge of a domain (implicit learning) requires conscious perception of the stimuli; and (2) if unconscious knowledge can be developed of symmetries, i.e. of regularities that go beyond statistical associations. The two issues that define the field of implicit learning are 1) the role of consciousness in learning and 2) the contents of what can be learned without awareness. The two objectives of **WP3** thus correspond to the two main issues that define the field.

WP4a: The limits of learning without awareness. **WP4a** is dedicated to exploring the limits of unconscious learning. There is a genuine puzzle in the fact that while the brain is an incredibly plastic organ, human learning always seems to be accompanied by awareness[103]. Most of the existing controversies in the domain of unconscious cognition[103-105] can be attributed to methodological disagreements. Beyond such issues, the main reason unconscious learning is so difficult to demonstrate with supraliminal stimuli is because awareness cannot be "turned off" and overrides unconscious processing. Masked stimuli, however, are inherently weak, and hence unlikely to be good targets of learning. Here, we will solve both problems by rendering the stimuli invisible while keeping them strong. To do so, we will leverage a new masking method called gaze-contingent crowding, which consists of (1) presenting flanker-surrounded stimuli in the periphery (16° eccentricity) and of (2) replacing the stimulus by a flanker as soon as the participant saccades toward it (monitored through eye-tracking). The method thus presents the advantage of enabling long presentation durations (i.e., seconds) while guaranteeing that participants never perceive the stimulus. We will use this method to investigate whether complex associative learning can take place with invisible stimuli by adapting Pessiglione (2008)[106]'s procedure, hoping to demonstrate, for the first time, sequence learning with completely invisible stimuli.

To investigate whether complex associative learning can take place with invisible stimuli, we will thus use the same instrumental conditioning paradigm as Pessiglione et al (2008). The learning task involves choosing between Go and No-Go response upon presentation of a subliminal sequence of 3 different arrows. One sequence will be associated with a reward and the other with a punishment; participant can win or lose money only if he makes the "Go" choice. This study would demonstrate that participant can learn a sequence of visual events without awareness of the rules that define the links between stimuli and without being able to consciously see the stimuli. The work will be carried out collaboratively between **INT2** (USussex — Dienes) and **P1** (ULB — Cleeremans).

WP4b: Imaging the transition between unconscious and conscious learning. **WP3b** is a direct follow-up to **WP4a** in which we focus on documenting the transition between unconscious and conscious processing. To do so, we will again use the same subliminal instrumental conditioning task as Pessiglione et al (2008)[106] with masked visual cues (one with a reward, the other with a punishment). In the original study, authors showed that learning performance asymptotes at 60% correct (chance level: 50%) with a differential activation between cues in the striatum. In this study, we will continue the training on masked cues until participants became consciously aware of the cues and consequently of the relationship between cues and outcomes. To evaluate awareness across different point of training, we will alternate blocks of learning task and blocks of trials determining objective and subjective visibility of the stimuli. We predict that the performance will increase dramatically until 100% correct when or shortly after participants become consciously aware of the stimuli. We also predict that the conscious learning would manifest by a differential activation between the cues in the prefrontal cortex. Like **WP3b,** the work will be carried out collaboratively between **INT2** (USussex — Dienes) and **P1** (ULB — Cleeremans).

WP4c: Awareness and the regulation of excitatory and inhibitory processes in human classical conditioning. Classical conditioning is assumed to be governed by two opponent processes, excitatory learning and inhibitory learning. While many theories regard these processes as symmetrical, we propose that excitation and inhibition might be fundamentally different, for instance as concerns their dependence on consciousness and working memory resources. Neurobiological evidence actually supports this assertion. We will develop a theoretical model that can account for such asymmetry. In a series of studies, we will then examine the claim that the degree to which conditioning procedures require contingency awareness for successful conditioning relates directly to the extent to which they invoke inhibition. Unravelling this asymmetry between excitation and inhibition might help to resolve discrepant findings in the literature concerning the possibility of conditioning in the absence of contingency awareness. This work will be carried out in collaboration with **P4** (KUL — Beckers), levering the partner's expertise on conditioning procedures.

WP4d: Implicitly learning symmetry. The previous three lines of work addressed the first objective of **WP4**. The next line of enquiry will address the second objective. The work will investigate whether people can unconsciously learn high-level regularities. We know implicit learning has definite limits. People do not readily implicitly learn arbitrary complex rules or even arbitrary simple associations. Instead, people most readily implicitly learn about structures that have high prior probabilities for being relevant[107,108]. One type of regularity that is not arbitrary, but of relevance to several domains, is symmetry. Leyton (1992)[109] argued that symmetries form the fundamental basis of perceptual and linguistic computations. The grammars above finite state in Chomsky's hierarchy uniquely produce various symmetries, such as, centre embedding (e.g. "the monkey *the man stroked* sighed"), defining structures that children apparently implicitly learn. People are sensitive to symmetry in other domains as well (see e.g. Reber, Schwarz, & Winkielman[110]). To detect a symmetry is, by definition, to find an invariant: That which is preserved across the different symmetric instantiations. Thus, detecting symmetry is computationally important, and allows for compression, faster encoding and easier storage of information. In sum, symmetry is not an arbitrary regularity, but one for which we have a high prior probability for believing could be implicitly learnt. Despite that, current computational models of implicit learning[111] would find learning symmetry per se difficult: Most models are connectionist, or reducible to a simple connectionist network, and connectionist networks have difficulty learning "operations over variables", as Marcus (2001)[112] put it, because networks characteristically learn to map specific values to values. (We need not agree with Marcus that learning operations over variables is impossible for connectionist networks in order to note that it is difficult.)

The proposed work will extend previous work in this lab, namely Dienes & Longuet-Higgins (2004)[113] and Kuhn and Dienes (2005)[114], which investigated the learning of certain symmetries in music. The new work will be conducted in two further domains where symmetry plays a role: Poetry and movement. Chinese Tang poetry has a mirror symmetry structure in the Chinese tones of successive syllables; movements have natural opposites, and obvious correspondences between the movements needed to go somewhere and those that take one back again. Thus these domains, in addition to music, are ones where there is reason to believe symmetry plays a role. Note all these domains are ones in which aesthetic judgments are relevant, and e.g. Reber et al.[110] argued symmetry is closely related to aesthetics. Thus, the implicit learning of symmetry is both likely to occur and to be a challenge to current theories and models of implicit learning. If we find it does not occur, it would count as a strong corroboration of existing models, it would have been a sincere attempt to falsify the models at their weakest point, and their survival would be all the more impressive.

The work will use movement by asking subjects to move around a circle, marked with 8 steps. This allows the movements to be exactly isomorphic to the tonal melodies used by Kuhn and Dienes (2005)[114], but we will use stimuli that tightens up various confounds that existed in the musical stimuli. As in the musical case, we will expose people to sequences instantiating the isomorph of a musical inversion, then ask subjects to rate their liking of inverses and non-inverses. For the artificial poetry we will copy the format of Tang poetry, which uses lines of five Chinese characters, where the Chinese tonal structure of paired lines are inversions of each other (using Chinese subjects). Again people will rate how much they like different poems, which will either instantiate inversions or not, while controlling the other structures we know people can implicitly learn (n-grams and repetition structures) as in the movement case. We can also investigate the relative ease of retrograde versus inverse symmetries, which has consequences for modelling (which we will actively explore), plus we will explore the generalisation of training to poems of different lengths, which is vital for determining if people have genuinely learnt symmetry per se.

WP5 — Mechanisms of human decision making: Conscious and unconscious influences

Lead Partner: P3 (UG – Brass)
Associated teams: P1 (ULB – Cleeremans & Peigneux) and **INT1** (UCL – Haggard)

The main goal of **WP5** part is to understand how different manipulations of top-down control (i.e. sleep deprivation, a belief manipulation and exhausted self-control) affect bottom-up influences on human decisions. Furthermore, we want to understand the brain mechanisms involved in such top-down influences.

Recent social psychological research has demonstrated that voluntary decisions strongly depend on unconscious processes [115]. However, how unconscious processes interact with conscious processes in human decision-making has hardly been investigated. This work package will investigate the brain mechanisms underlying conscious and unconscious sources of intentional decisions. The basic hypothesis is that the degree to which a decision is biased by unconscious sources is reciprocal to the intentional involvement in a decision. To give an example, if one is tired or exhausted it becomes much more likely that a decision is guided by habits or the context (bottom-up influences) which are the result of the learning history rather than explicit deliberation (top-down influences).

Recent research from our group suggests that bottom-up and top-down influences on human decisions can be dissociated at the brain level [116]. Decisions that followed a bottom-up bias (a learned relationship between the stimulus and a specific decision) activate the so-called default mode network [117] while decisions that were unbiased involve the intentional action network [118]. However, research so far did not systematically test to what degree bottom-up influences on intentional decisions depend on the level of consciousness. Furthermore, it has not been investigated to what extend the influence of bottom-up effects depends on the degree of top-down control. In the current work package we will independently manipulate the degree to which bottom-up and top-down sources influence human decisions, using different paradigms. In the first part of the project we will investigate the role of consciousness on bottom-up influences. In the second part we will investigate how manipulating intentional involvement in a decision affects the strength of bottom-up influences. We will use behavioral as well as brain activation measures. On the brain level, we will carry out multivariate pattern analysis (MVPA) to predict intentional decisions from brain activity [119]. This new technique allows determining the brain areas carrying predictive information at different points in time. Furthermore, this method allows computing the accuracy with which a decision can be predicted from brain activity before participants become aware of their decision. This will enable us to quantify the degree of bottom-up and top-down influences on human decisions.

WP5a: The role of consciousness in bottom-up influences on intentional decision. The first part of the project will investigate the role of consciousness on bottom-up influences. In collaboration with **P1** (ULB — Cleeremans) and **INT1** (UCLondon — Haggard), we will manipulate the degree to which intentional decisions are biased by unconscious and conscious information using implicit learning [e.g. 120] and subliminal priming [121]. In an intentional decision paradigm participants will be asked to freely decide between two response alternatives with the only restriction to choose each alternative equally often. While participants carry out the task, they observe a sequence of letters occurring on the computer screen [119]. After each decision, they have to indicate which letter was on the screen when they decided. Importantly, some letter sequences will be related to a specific response sequence in a previous training session. The degree to which participants become aware of this learned sequence will be manipulated and tested using different measures of consciousness [122]. We will investigate whether activity in the default mode network varies with the degree to which participants become aware of the sequence. We predict that awareness will reduce the bottom-up bias. Hence, participants will less often decide for the biased response alternative. Furthermore, brain activation in the default mode network will be reduced and prediction accuracy will decrease.

While the first part of the project will use learning to induce a bottom-up bias, a second series of experiments will use subliminal and supraliminal priming procedures to bias human decisions [121]. Again, we predict that subliminal priming will lead to a stronger bottom-up bias on intentional decisions than supraliminal priming. Furthermore, activity in the default mode network will be higher for decisions that follow a subliminal compared to a supraliminal prime.

WP5b: Ego-depletion and top-down influences on intentional decisions. The second part of the project will investigate the role of intentional involvement in decision-making. Here, we will use so-called ego-depletion manipulations that are known to impair intentional effort or willpower [123]. In collaboration with **P1** (ULB — Peigneux), we will use the sleep deprivation paradigm to decrease the ability to recruit intentional processes in a decision task. It has been shown already that sleep deprivation impacts on attentional networks [124,125] and working memory [e.g. 126]. Additionally, neuropsychological and neuroimaging studies indicate that sleep deprivation impacts on higher-order prefrontal-related executive functions such as decision-making [127,128]. Yet, no study to our knowledge has investigated yet whether and to what extent sleep impacts on the balance between bottom-up and top-down influences on intentional decisions. Therefore, in a series of behavioral experiments we will test whether sleep deprivation increases the bottom-up bias on intentional decisions. We will use experimental manipulations that have been developed in the first part of the project to manipulate the bottom-up bias. We will then carry out a within-subject fMRI experiment (i.e. participants will be tested two times, in a rested and a sleep-deprived condition) where we will test whether sleep deprivation selectively reduces activation in the intentional action network, and whether brain activation concurrently increase in the default mode network, leading to a better predictability of human decisions from preconscious information.

In a second series of experiments, we will use social psychological manipulations to reduce the intentional involvement in a task. Indeed, social psychological research has demonstrated that manipulating attitudes towards free will influences the way people interact with their social environment [129,130]. In a recent study, we showed that inducing disbelief in free will actually impacts on intentional motor preparation [131]: participants that read a text questioning free will showed a reduced readiness potential. In the current set of experiments we will investigate whether disbelief in free will lead to a reduction of the top-down influences on intentional decisions and therefore make us more susceptible to bottom-up influences. Preliminary evidence suggests that disbelief in free will indeed increases the bottom-up bias on intentional decisions.

Finally, we will use classical ego-depletion manipulations to reduce the top-down influence on intentional decisions. One efficient ego-depletion manipulation is to asked participants to exert self-control over a long period of time (e.g. resisting eating chocolate when being hungry). Then participants will again carry out the intentional choice task and we will investigate how this ego-depletion manipulation influences the bottom-up bias on intentional decisions.

WP6 — Mechanisms of instrumental learning and the conscious experience of agency

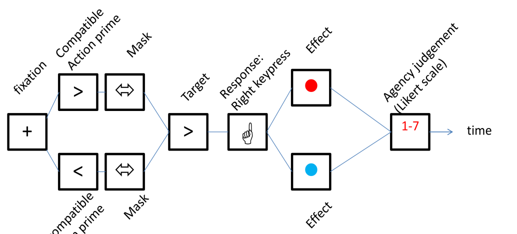
Lead partner: INT1 (UCL – Haggard)
Associated teams: P1 (ULB – Cleeremans) and **P3** (UG – Brass)

The sense of controlling our own actions, and through them events in the outside world, is a fundamental feature of human mental life. The mechanisms underlying this "sense of agency" are poorly understood, though animal learning studies have revealed the basic brain mechanisms of learning and prediction on which sense agency seems to depend[132]. We recently showed (Wenke, Fleming and Haggard[133]) that sense of agency depends not only on the actual result of our actions, but on how efficiently we select which action we perform. When actions were subliminally primed with a compatible left/right cue, participants felt greater control over a subsequent visual effect triggered by the action, compared to when the primes were incompatible. These primes did not predict the effects of action, but simply influenced the ease of action selection. Thus, this aspect of the conscious experience of agency must be *prospective*, rather than being *retrospectively* based on action-outcome relations. People frequently report the experience of knowing exactly what to do in a given situation: we suggest this reflects a sense of agency based on selecting what to do, rather than based on action outcomes.

WP6 will study the role of instrumental learning in conscious sense of agency. We hypothesise that people must first learn the relation between actions and their consequences: only then can efficiency of action selection be a reliable component of sense of agency. That is, action selection can only contribute prospectively to sense of agency if participants have learned how the selected action actually influences external outcomes. We therefore predict that the contribution of subliminal priming of actions to conscious sense of agency should develop during action-effect learning. To test this hypothesis, participants will learn a statistical relation between 4 different response keys and 4 different shapes of a visual stimulus caused by the keypress. For example, response key 1 will produce a square on 80% of trials, but a circle, triangle or diamond on the remaining 20%. Response 2 will produce a circle on 80% of trials, but a square, triangle or diamond on the remaining 20% and so on.

WP6a: Effect-priming: Objective measures of instrumental learning. Participants are informed by a target arrow cue pointing left, right, up or down regarding which response key to press. On some trials, these target cues are preceded by subliminal EFFECT primes that represent the shape of the visual stimulus shown after the response. If the effect prime shows the effect that most commonly follows the response corresponding to the target arrow cue (e.g., the prime shows a square, and the target cue indicates response 1) then the effect prime is compatible, otherwise it is incompatible. Once participants have learned the statistical relation between action and subsequent visual shape, compatible effect primes should pre-activate the response associated with the effect[134], resulting in faster reaction times to target arrow cues, relative to incompatible effect primes. The acceleration of reaction times by compatible primes allows objective measurement of instrumental learning.

WP6b: Action-priming: Objective measures of action selection efficiency. In addition, the design includes a second dimension of priming, related not to outcomes of action, but to fluency of action selection. On some trials, a subliminal ACTION prime will appear prior to the target cue. The action primes are identical to the target arrow cues, but presented briefly, and followed a pattern mask, so that they cannot be discriminated. An example of one trial is shown in figure **F6.1.** The action primes will be compatible or incompatible with the subsequent target arrow cues. Compatible action primes should lead to faster reactions to the target arrow cues than incompatible action primes. Crucially, the action priming effect is independent of the relation between action and outcome. Therefore, action priming should influence reaction time whether participants have learned the relation between their response and the subsequent visual shape or not. We will randomly intermix effect priming trials and action priming trials. Effect priming depends on instrumental learning of action-outcome relations, while action priming reflects the fluency and efficiency of selecting between motor intentions, and is logically independent of instrumental learning.



F6.1: Structure of a trial in a typical action priming experiment. Subliminal primes are compatible or incompatible with a subsequent target. Notice that different colours are shown after compatibly- and inompatibly-primed trials. Participants judge how much control they have over the colour that appears after their response. Greater control after compatibly-primed trials is taken as evidence that action selection processes contribute prospectively to sense of agency.

WP6c: Subjective sense of agency: prospective efficiency of action selection vs. instrumental control. We will assess sense of agency by asking participants to rate how much control they feel over the coloured shapes that follow actions. The prospective aspect of sense of agency can be investigated by testing how action priming influences the feeling of control over action effects. The visual stimuli that follow each response will be presented in a variety of colours. Whereas the shape of these stimuli is related to the response key that caused them, the colours are statistically unrelated to which key is actually pressed. Instead, colours are related to the compatibility of the primes. Briefly, one set of colours is shown after compatibly primed responses, and a second set after incompatibly primed responses. After each trial, participants judge to what extent they were in control of the stimulus that followed their response. We predict that trials with compatible action primes (i.e., first set of colours) higher levels of control than incompatibly primed trials (second set of colours). This would confirm the prospective contribution to the sense of agency we identified previously. That is, sense of agency depends not only on our actions and their effects, but on how efficiently we arrive at a plan or intention for action. Compatible action priming would increase the efficiency of intentional action selection, with consequent effects on sense of control.

We also predict that conscious sense of agency will depend on action-outcome relations. Participants should experience a stronger sense of agency when their action is followed by a compatible visual shape than by an incompatible visual shape. They may also experience a stronger sense of agency on trials where the effect has been primed in advance. Moreover, sense of agency judgements should emerge as instrumental learning of action-outcome relations develops.

WP6d: Does the prospective sense of agency depend on instrumental learning? Here, our interest focuses on whether this prospective aspect of agency is related to instrumental learning or not. We predict that the prospective contribution to agency, defined as the difference in agency ratings between compatibly and incompatibly primed trials, will initially be low, and will gradually increase as participants learn the contingent instrumental relation between their responses and the size of the ensuing stimulus. By comparing the prospective contribution to sense of agency across successive blocks, we will test how closely the conscious sense of agency tracks actual instrumental learning. If the prospective sense of agency develops in tandem with instrumental learning, we would conclude that learning the impact of our actions on the external world is necessary for us to be conscious of our intentions. If, conversely, the prospective sense of agency is unrelated to instrumental learning, we would conclude that the prospective sense of agency is an illusion, in which people confuse the strength and clarity of their intentions with their intentional ability to influence the external world. Thus, these experiments will investigate a crucial question about consciousness: does it track our learning and our actual agency, or is it a "user illusion" that is poorly related to our actual performance?

WP6e: fMRI study. We have suggested above that action priming and effect priming can be used to measure prospective sense of control, and objective instrumental learning, respectively. In collaboration with **P3** (UG — Brass), we will assess interactions between these two processes in fMRI. Briefly, we will compare BOLD activity for effect priming and action priming in a 2x2 design, while asking participants to rate the experienced sense of control over effects of action, as above. We predict that compatible effect priming will activate striatal reward networks, relative to incompatible priming, while compatible action priming will activate lateral prefrontal and premotor action selection networks relative to incompatible priming. We will use parametric fMRI designs to investigate neural correlates of the development of these effects over the course of each short block. More particularly, we predict increasing effective connectivity between instrumental learning networks and action selection networks as the block progresses. This may provide the neural substrate that allows the prospective contribution of action selection to subjective sense of control to become increasingly important with learning. Such results would provide a convincing mechanistic explanation of why, once we have learned a degree of control over a machine, for instance, simply selecting the right command to send to the machine generates a sense of fluent mastery, even before the machine's actual response is known.

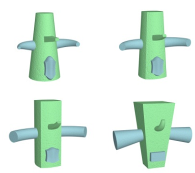
WP6f: Can implicit learning support conscious sense of agency. We hypothesise that instrumental learning is required for the prospective sense of agency to develop. If this is established, follow-up experiments will investigate whether this learning needs to be conscious and explicit, or whether implicit agency learning is sufficient. **P1** (ULB — Cleeremans) will collaborate in designing the conditions and measures of action-outcome learning for this experiment. We will increase the complexity and contingency of the mapping between responses and visual shapes. For example, if each response is followed not by a single shape, but probabilistically by any of several different shapes, instrumental learning should still be possible, and reaction time differences between compatible and incompatible effect primes should remain. However, it is less clear whether subjective judgements of agency will still be affected by action priming. We will test whether the prospective component of conscious sense of agency can develop even when action-outcome relations are only implicitly learned, and participants can no longer explicitly track action-outcome relations. The answer to this question will directly compare the sensitivity of instrumental learning with the sensitivity of conscious sense of agency, for the first time. We predict that instrumental learning of an action-outcome response is a necessary but not sufficient condition for acquiring a prospective sense of agency. Put another way, prospective agency requires an additional conscious step of action selection, over and above mere action-outcome associative learning.

WP7 — Mechanisms of awareness: Learning to be conscious

Lead Partner: P1 (ULB – Cleeremans)
Associated teams: P3 (UG – Brass), **P5** (UCL – Rossion), **INT1** (UCLondon – Haggard) & **INT2** (USussex – Dienes)

The main goal of **WP7** is to explore the contributions of conscious and unconscious learning to consciousness. We examine this issue from a dynamical perspective, putting the emphasis on (1) contrasting different methodologies to assess awareness, and on (2) on exploring the non-monotonic dynamics of consciousness, at different time scales (within-trial processing, learning, & development). Because the workplan for this WP is substantial, its presentation is split in three parts. **WP7a** is focused on manipulations of quality of representation. **WP7b** is focused on manipulations of metarepresentations. **WP7c** is dedicated on exploring the provocative idea (the "radical plasticity thesis" [135] that learning mechanisms actually subtend the emergence of consciousness.

WP7a: Consciousness depends on quality of representation. A first core idea that we will here explore is that the extent to which a representation is available to consciousness depends on quality of representation (QoR). QoR depends on bottom-up stimulus properties, on top-down factors such as task instructions or attention, and accrues as a result of learning. Three properties are assumed to contribute to a representation's quality: Its strength, its stability in time, and its distinctiveness [136]. WP1a is dedicated to providing empirical support for these ideas. To do so, we propose several series of studies, as follows:



F7.1: Penguins

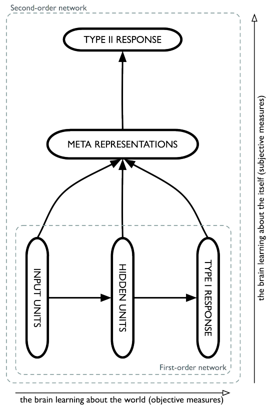
In **Study 7a.1**, we will manipulate properties of the stimulus and assess the influence of such manipulations on awareness. In a psychophysical design using, participants will perform an identification task using a four-choice forced alternative (4AFC) procedure. Dependent measures will be (1) identification accuracy, (2) phenomenal experience as assessed by the PAS scale. Stimuli will be novel multi-part objects created by **P5** (UCL — Rossion) called penguins (Figure **F7.1**). In Study **7a.1a**, we will manipulate strength by systematically varying the number of times each object is presented, as in Marcel (1983)[137]. In Study **7a.1b**, we will manipulate stability by varying the duration of presentation of each stimulus in small steps, similar to Del Cul et al. (2007)[138]. Finally, in Study **7a.1c**, following Archambault et al.[139], we will manipulate the distinctiveness of each object by training participants to identify some objects at a specific level (each individual object has a name) and others at a general level (some objects are defined as family A or as family B). Higher distinctiveness in the first group should lead to better awareness in the post-training test, which will consist either of a subliminal perception[137,140] (SP), or of an Attentional blink[141] (AB) task. The first involves weak, but attended stimuli, while the second involves strong, but unattended stimuli. Local synchrony and occipito-temporal activity is observed when unattended supraliminal stimuli are processed, which is not the case for attended subliminal material. One would therefore expect learning effects to be more apparent in the AB paradigm than in the SP paradigm.

If consciousness is something that one learns, then we should be able to demonstrate that training modulates perceptual experience. This is what we will test in **Study 7a.2**, through three different strategies. In all three studies, we will track how the respective dynamics of performance, awareness, and metacognitive accuracy change over time. Performance will be measured by a 4AFC task, awareness by the PAS scale, and metacognition through confidence ratings. First (**7a.2a)**, we will compare expert and novice performance on overlearned stimuli by asking Chinese and Western participants to identify masked Chinese and Maya signs in a psychophysical design where stimulus duration is varied. We expect to find not only better performance but also better subjective visibility reports in the Chinese group when processing Chinese stimuli. Second, (**7a.2b**), we will train participants to become experts for certain visual objects (the penguins depicted in **F1**). The training procedure, will be adapted from Rossion et al.[44]. Participants will perform either an SP or and AB task at three different points during training, which will extend over 10 hours. We predict a modulation of subjective visibility in both the SP and AB tasks. Third (**7a.2c**), we will train participants directly on performing the AB and SP tasks themselves on highly familiar materials (numbers). Finally, in **Study 7a.2d**, depending on our results, we will adapt some of the experiments to brain imaging methods to track the neural changes associated with training. We will specifically focus on (1) documenting the increase of an N170/M170 component[43,142], known to be involved in high-level perception of visually experienced stimuli stimuli, as a marker of visual awareness and on (2) exploring how ventral occipito-temporal cortex activity interacts with other areas over the course of training.

Studies 1a.3-1a.5 will directly test a critical prediction of the QoR framework, namely that automatization should result in increased performance but *decreased* awareness. In Study **7a.3**, we focus on perceptual learning, in which subjective visibility is seldom assessed[143]85]. Here, we will use a diamond vs. square perceptual learning task where stimulus visibility is manipulated through metacontrast masking. Discrimination training will be interleaved with three test sessions. Two test conditions will be contrasted. In the first, participants perform the discrimination task and report on their experience of the stimulus in 100% of the trials. In the second condition, participants only report visibility in 5% of the trials. We expect performance and visibility judgements to be low prior to any training. On the second test (explicit phase), both performance and visibility judgements should have improved substantially. The third test (automaticity) is critical, for we now predict further increased performance, but, crucially, *decreased* visibility ratings in the 5% test condition only (as participants do not have to monitor their performance continuously in this condition). Automaticity in discrimination ability will be assessed post-hoc by asking participants to perform the discrimination task again concurrently with another, secondary task. In **Study 7a.4**, we focus on motor awareness by using Seibel (1963)[144]'s paradigm, in which people respond to all combinations of 10 visual stimuli by pressing on combinations of 10 corresponding keys in a 1023-choice reaction time task. Seibel only recorded global reaction times, however, and while this was sufficient to demonstrate the power law relationship between RTs and training, it is neither sufficient to explore the mechanisms through which participants form chunked representations of the required finger movements, nor to assess action awareness. Here, we will replicate for the first time Seibel's seminal experiment using an fMRI-compatible custom keyboard that we have recently acquired and that makes it possible to record response times to individual targets. Participants will perform 30 blocks (1023 trials; one each day for *30 days*) of the 1023-choice RT task. Five blocks (#1, 2, 4, 10, 30) will be performed in the fMRI scanner. Further, on 10% of the trials, participants will be prompted to reproduce the response they have just produced, so as to probe action awareness. We expect action awareness to show a non-monotic relationship to performance, as predicted. **In Study 7a.5**, we focus on cognitive control by replicating Cohen, Dunbar & McClelland (1990)[145]'s shape-color Stroop task, which involves tracking the emergence of automaticity over about 20 hours by training participants to associate color names to shapes and assessing interference through incongruent trials in a shape-naming task administered at regular intevals. Choice reaching will be used here to track the locus and dynamics of control. Subjective experience will be assessed as in Study 1a.3.

Studies 7a.6 & **7a.7** are dedicated to assessing the effects of either perceptual or memory priors perceptual experience. In **Study 7a.6**, we will use the phenomenon of hysteresis to show that perception is influenced by context. Viviani[146] demonstrated that a rotating dot which velocity varies is perceived either as tracing a circle or an ellipse. Here, we will present such stimuli in a sequence that goes from circle to ellipse, or from ellipse to circle, and ask participants, on each trial, (1) to judge the extent to which the stimulus is circular, and (2) to reproduce the stimulus's trajectory as accurately as possible (tracking movements). We expect judgments to be influenced by the starting point of the stimulus sequence (hysteresis), so that people will judge the middle stimulus to be more circular than it really is if the sequence began with a circle. Movements should not be influenced. We further expect judgments to be influenced by whether reproduction took place before or after the judgment, which would suggest that perception has a postdictive character. In **Study 1a.7**, we will manipulate the strength of memory representations by using a four-choice discrimination task in which stimuli are patches of Gaussian noise briefly presented in a square arrangement on a background of white noise. On each trial, people have to identify the densest Gaussian patch and respond to its location by pressing on a corresponding key. Unknown to participants, the sequence that the target stimulus follows from one trial to the next is determined by a repeating sequence. Previous research has demonstrated participants can learn such material implicitly: The more people learn about the sequence, the better they anticipate the next response[147], in the absence of explicit knowledge. Here, we ask whether such learning also modifies people's perceptual experience of the stimulus. We expect to find lowered visibility thresholds (as assessed through PAS) for predictable trials than for unpredictable trials, up to the point where people will claim to have seen the stimulus even when it is absent from the display (an hallucination). This would confirm that awareness depends not only on quality of representation, but also on predictive metarepresentations.

WP7b: Consciousness depends on Metarepresentation. The goal of **WP7b** is to test a second core idea, namely that a representation (of sufficiently high quality) is a conscious representation only when that representation is itself the target of metarepresentations. High-quality first-order representations can make an agent *sensitive* to some state of affairs, but sensitivity does not amount to *awareness*, which always involves, at least potentially so, knowledge that one knows. **Study 7b.1** is dedicated to develop a computational model of the dynamical relationships between behaviour, consciousness and metacognition., building on original work that we have just begun developing[148,149]. In the architecture depicted in **F7.2**, two networks interact: A first-order, feedforward network learns about the world by linking perception to action, while a second-order, independent network learns to redescribe the internal states of the first-order network in the service of another task (wagering on the accuracy of the first-order network's responses), so learning about itself. The model captures the central intuition of Higher-Order Thought Theory[150,151] that it is when one is conscious *of* possessing some knowledge that the knowledge is conscious and the central intuition of Karmiloff-Smith's Representational Redescription Theory that development involves redescribing one's knowledge to oneself[152]. In its current incarnation, however, the model is more a proof of concept than a fully developed architecture. Here, we will develop the model in three directions. First, to capture the dynamics of information processing, the model needs to be fully dynamical itself, making it possible to capture the fine-grained time course of processing. Second, the model needs to be recurrent: the second-order network should be allowed to influence first-order processing. Both of these goals require switching to considerably more complex simulation methods such as the LEABRA algorithm[8]. Third, the model needs to be compared in detail both to forward-inverse models[153,154] and to recent developments in Signal Detection Theory[155-157]. As it stands, however, the model already makes specific predictions. First, it uniquely predicts that metacognitive accuracy is non-monotonic over the course of learning: Accuracy in judging whether the first-order network is correct or not in its decisions is initially high (because the second-order network quickly learns to predict that the first-order network is always wrong), decreases with further training (because it now takes chances with its predictions) and ends up associated with first-order performance later on. Confidence should follow the same course in humans. Second, it predicts that it should be possible to manipulate metarepresentations independently from first-order representations. The model thus suggests three different strategies through which to explore the dynamical interplay between action, awareness, and metacognition. A first possibility consists of leaving first-order representations intact while eliminating metarepresentations (**Studies 7b.2-7b.3**). A second possibility consists of manipulating metarepresentations and to assess the effects of such manipulations on both performance and awareness (**Studies 7b.4-7b.6**) A third possibility consists of exploring disturbances in metacognition (**Study 7b.7**).



F7.2: A metacognitive network

Studies 7b.2-7b.3 will attempt to eliminate or interfere with metarepresentations. In addition to the studies described in **WP3a-b**, in which we attempt to eliminate awareness altogether, we here propose to interfere with the development of metaknowledge in different points during training in a sequence learning task and to assess the consequences of such interference on reportability of sequence knowledge. In **study 7b.2**, participants will be asked to perform a concurrent, attention-demanding secondary task either at the beginning, in the middle, or at the end of training. We expect interference to be maximal in the middle of training, when metaknowledge first emerges. In **Study 7b.3**, we will use Theta-Burst Transcranial Magnetic Stimulation[158] applied to the bilateral Dorsolateral Prefrontal Cortex to decrease metacognitive sensitivity while leaving performance intact in different paradigms adapted from the studies of **WP7a** and assess the effects of such stimulation on the time course of the different measures.

Studies 7b.4-7b.6 seek to manipulate metarepresentations rather than eliminate them. **In Study 7b.4**, we will do so by using hypnosis, placebo, and non-hypnotic suggestion and compare their effects on the dynamics of performance, awareness, and metacognitive accuracy. We have reason to think that all three procedures induce changes in people's conscious expectancies[159]. Yet, no systematic study comparing the three methods exists. Here, we will carry out this systematic comparison using two paradigms: the Attention Network Task[160], which tests different aspects of attentional processing (alerting, orienting, executive control), and pain perception. Five groups of participants will be compared: Hypnosis, placebo, non-hypnotic suggestion, controls, and simulators (people instructed to act as though they were highly hypnotizable). This work will be carried out in collaboration with **P3** (UG — Brass) and can be viewed as complementary to the work that will be carried in **WP4b** (Ego-depletion and top-down influences on intentional decisions). In **Study 7b.5**, we focus on the Perruchet effect, which we have contributed to identify[161] and which shows that online conscious expectancy is completely dissociated from reaction time in a simple associative learning task where temporal context is manipulated so as to induce the Gambler's fallacy. The paradigm thus uniquely offers the possibility of imaging the neural correlates of conscious expectancy and automatic priming in a situation where they dissociate, which is what we will endeavour to do in an fMRI design. Finally, in **Study 7b.6**, we will explore interactions between stimulus complexity and task instructions. It is striking to note that different studies have incongruently reported either anterior[162] or posterior[163] correlates of consciousness. We surmise that these differences stem from an overlooked confound, namely stimulus complexity: Studies reporting posterior correlates have all used simple stimuli (gratings) whereas studies reporting anterior correlates have used complex stimuli (numbers). Here, we will manipulate level of processing while keeping the stimuli identical. Participants will perform a discrimination task on coloured numbers and will either judge the magnitude of the numbers or their hue. We hypothesize that stimulus duration will interact with the task (simple vs. complex) so as to show a graded transition from unconscious to conscious processing in the hue condition and a non-linear transition in the numerical condition. We further expect to find, with EEG/MEG, a more posterior ERP component to correlate with subjective reports in the hue task, but a more anterior component in the numerical task.

In **Study 7b.7**, we turn to disturbances of metacognition. Recent findings[164] have shown that metacognitive accuracy exhibits considerable individual differences characterized by both structural and functional differences in frontal cortex. Here, we will study pathological gamblers (PG), whom we will ask to perform decision making under uncertainty with the Iowa Gambling Task[165]. Studies[166,167] have shown that PGs are overconfident and exhibit more risk-taking behaviours prior to erroneous choices. Furthermore, PGs erroneously hold the belief that they can exert some control over the events that the bets are placed on[168,169]. Metacognition will be assessed through post-decision wagering[26]. Here, we expect PGs to exhibit deficits in both their performance and in their metacognitive judgments, that is, they should both perform more poorly than controls and simultaneously exhibit overconfidence in their decisions. If the behavioural experiment is successful, we will then explore PGs' metacognitive accuracy in a perceptual task modelled after that used in Study 1.4, and replicate the study using fMRI to explore the neural correlates of such biases.

WP7c: Consciousness depends on learning. The main goal of **WP7c** is to explore the "inner loop", that is, the mechanisms through which the brain predicts, learns about, and redescribes its own activity to itself. This internal "representational redescription"[3] process is hypothesized to be constitutive of consciousness by means of Higher-Order Thought Theory [150]. There is considerable evidence that the brain can reorganize itself in profound ways through mechanisms of plasticity. Taxi drivers have larger posterior hippocampi than bus drivers[170] (for the former engage in spatial problem solving while the latter do not); expert players of string instruments show plasticity-driven changes in the representation of the tactile sensations stemming from the fingering digits[171]; individual medial temporal lobe neurons show stunning response selectivity to cultural icons such as the American actress Halle Berry[172]. There are even suggestions[173] that the very anatomical structure of the sensory cortex (the "Penfield homunculus") is shaped by in-utero learning (specifically, sensitivity to random, but correlated tactile stimulation on the face and hands and on the feet and genital organs, which are represented close to each other in the Penfield homunculus and are, crucially, close to each other when in the foetal position). As such, however, our hypothesis is extremely difficult to test directly short of resorting to connectivity and Granger-causality methods[174] (which we will consider exploring). Instead, we will focus on establishing that people can learn to us previously implicit or novel information to modulate their experience. To do so, we will track the dynamics of the emergence of novel experiences through neural feedback and sensory substitution methods.

In **Study 7c.1**, in collaboration with **INT1** (UCLondon — Haggard), we will use EEG-based neurofeedback to find out whether people can use information about their own brain activity to learn to fill the gap between intentions and actions. Participants will perform the Libet (1983) task[175], in which they are asked to spontaneously move their hand while attending to a continuously moving clock hand so as to be able to subsequently report when they first "felt the urge" to move. Using EEG, Libet showed that conscious experience of intention to act occurred about 350ms *after* the onset of the lateralized readiness potential, so suggesting that unconscious motor activity *precedes* conscious intention, a finding that famously questioned the concept of free will[176,177]. Libet's experiment has recently been replicated[178,179]; most recently using fMRI[180]. Here, we propose to test the idea that the temporal gap observed by Libet between brain activity and conscious experience of intention can be reduced through neurofeedback by providing participants with information about premotor activity recorded at electrode Cz. Interestingly, recent studies[176] have questioned Libet's findings by suggesting that the predecisional negative shift at Cz not only reflects motor preparation but is also caused by the requirement to monitor the clock. Our results offer a way of testing this possibility. In follow-up studies, we will also explore the idea that such neurofeedback can be used implicitly.

In **Study 7c.2**, we will exploit the same idea to find out whether feedback about subpersonal decision-making can be used participants, either consciously or not, to change their metacognitive accuracy. To do so, single-trial electromyography will be deployed in a neurofeedback design. Participants will perform a difficult identification task modelled after **Study 7b.6** and will visualize their online subthreshold muscular activity on each trial.

WP8 — Mechanisms of cultural learning

Lead Partner: P1 (ULB – Kolinsky & Content)
Associated teams: P5 (UCL – Rossion) & **P2** (UG — De Houwer)

WP8a: Neural recycling and neural competition. In comparison to primary abilities like speech and vision that are acquired unintentionally and implicitly by mere exposure to the regularities of relevant stimuli, literacy is often considered as a secondary ability[181], requiring explicit teaching and intentional learning. Although no sufficient time or evolutionary pressure may have led to the development of a devoted brain system within a genetic basis, we now begin to understand that learning a script not only creates a specific circuitry for processing written material, comprising the left fusiform gyrus, and more specifically the so-called "visual word form area" (VWFA, e.g., Cohen et al.[182]; Dehaene & Cohen[183]), but also deeply impacts on the organization of the phylogenetically and ontogenetically older processing systems of speech and vision, including at the brain level[184]. This is in agreement with the *neuronal recycling hypothesis* [184,185], according to which learning to read involves adapting the existing cognitive architecture to solve this novel cultural task. Most impressively, such feedback effects from literacy are not limited to language. Literacy has indeed been shown to affect non-linguistic visual processes at the brain level. In our recent fMRI study comparing illiterate to literate adults[184], we showed that at the VWFA site, learning to read competes with the cortical representation of other visual objects, especially with faces. While the left VWFA becomes increasingly responsive to letter strings as individuals acquire reading, it becomes decreasingly responsive to faces, which become more right lateralized in literates compared to illiterates. We will aim at understanding what exactly such neural competition effects reflect, and how widespread they are. These studies will be conducted on both illiterate vs. literate adults and preliterate vs. literate children, using behavioral, eye movement recordings and event-related potentials (ERPs), leveraging **P5** (UCL — Rossion)'s expertise on face processing.

First, we will aim at identifying the behavioral correlates of the neural competition between written words and faces, as it raises the intriguing possibility that face perception suffers as reading skills develop. We will compare the ability (relative accuracy and speed) to perform various face tasks in literate and illiterate individuals: matching of unfamiliar faces and control visual patterns (with and without changes in viewing conditions between the stimuli to match), as well as learning and recognition tasks. Then we will test whether literacy modulates face processing in a *qualitative* manner: does it affect holistic (i.e., integrative) or analytic (i.e. part-based) processing of faces? Within the face domain, it has been shown that adults "experts" on children faces (schoolteachers) have a reduced holistic processing – as indexed by the composite face effect[186]– for adult faces[58]. The heart of our expertise with faces appear to lie in holistic perception[187], and it has been recently argued that expert word recognition also partly relies on holistic processing, with composite effects modulated by reading experience and the holistic processing it reflects being sensitive to amount of experience (it is stronger for native than second-language readers, and stronger for words than pseudo-words in native readers[188]. To test whether literacy modulates holistic face processing, we will use behavioral tasks involving the inversion[189] and composite face effects[186], as well as gaze-contingency using eye movement recordings. This latter method was developed originally in the reading literature[190,191] and has been recently successfully applied to face perception to contrast holistic and analytic processing. In this section, we will also address the issue of balanced processing between left and right hemisphere processing[192,193]. Regarding reading, it has been argued that efficient processing is attained thanks to a balance between decoupled left and right hemispheric activity (compared to good readers, poor readers show enhanced activation for written words in right occipito-temporal area[194] and activation of left/right regions involved in reading is enhanced/decreased after reading remediation[195,196]. As regards faces, we observed more decoupled fusiform activation in literates[184]. Here, we will test whether these observations lead to behavioral consequences using lateralized stimulation: the right hemispheric advantage for faces, as measured through divided visual field presentation[197] or chimeric effects[198] should be stronger for literate than illiterate individuals.

Second, we will address the question of the time-course of the effect of literacy on processing visual materials by using ERPs. Indeed, one outstanding question is whether learning to read affects the *early* activation of the representation of other complex visual stimuli such as faces. In literate individuals, the N170 component, the first activation of face representations in the human brain, is larger in the right hemisphere for faces and massively left lateralized for written material[199]. However, the effect of literacy on such a basic ERP response is unknown. A concurrent stimulation paradigm in ERPs[200], in which participants fixate a central word while faces are presented laterally, will also be used to directly measure the competition effects between faces and written material in literate and illiterate individuals. Finally, we will also use ERPs to test the hypothesis that competition effects found in literate individuals depend on processing demands rather than on kind of material: when processing written material on the basis of script style (e.g., font or handwriting style) rather than word identity, we hypothesize to observe fewer[201] differences between literate and illiterate individuals in the neural representation of words and of faces.

Third, we will check whether neural competition only reflect feedback effects from new cultural abilities on older systems (i.e., recycling), or are more general. Can similar competition arise when *expertise* is gained in a *non-cultural skill*, like face processing? To examine this question, we will target extreme individuals in face processing, i.e. congenital cases of "prosopagnosia" [202], as well as "super-recognizers"[203], i.e. people who are much worse or much better than the average at face recognition, respectively. They will be tested at a variety of reading tasks, with the hypothesis that their reading abilities will be inversely correlated with their face processing abilities, under the neural competition hypothesis. Moreover, as indicated above, there is evidence that efficient processing is attained thanks to a balance between decoupled left and right hemispheric activity, but it remains unclear whether increased right lateralization in face processing would be associated with superior abilities. This will be tested by comparing lateralization of processing between cases of congenital prosopagnosia and super-recognizers.

We will also examine whether competition effects can be observed *between newly acquired, symbolic, systems*. To this aim, we will examine bi-literate individuals or individuals who are taught a new script, different from the one formerly learned. Previous work has shown than in such a situation (e.g., with Japanese learning the Korean Hangul script[204]), responses of the VWFA to the newly acquired script increases with learning in a way correlated with increase in reading performance in this script. We ignore, however, how this affects the VWFA responses to the first script, compared to mono-literates. As a control for the differences in script complexities, which may modulate brain activation[205], we will study a special population, namely congenitally blind people, who use exactly the same script (Braille) for representing the alphabet and music notes. Indeed, we know that in these individuals Braille reading is subtended by the VWFA[206]. In these blind people, will learning of musical notation interfere with the responses of VWFA to words? Finally, at the theoretical level, in collaboration with **P1a** (ULB — Cleeremans), we will try to relate these competition effects with more general theories of learning and interference between learned abilities.

WP8b: Does learning new cultural categories modify natural categories? Beyond the environmental-based changes in basic speech perceptual categorization processes linked to linguistic experience, we know from previous work that literacy deeply affects speech processing. There are indeed strong functional connections between the speech and written systems, with both feed-forward and feedback connections between phonology and orthography.

We have contributed to demonstrate the influence of orthographic knowledge on-line spoken word recognition[207] and memory for spoken strings[208]. These results on literates converge with our comparative fRMI data on illiterate and literate adults[184]: in auditory lexical decision, literates display activation of the VWFA by spoken inputs; they also show activation by written inputs of the left perisylvian language areas. The feedback connections develop rapidly in the course of learning to read, as demonstrated in our developmental studies on orthographic effects on spoken word recognition[209]. Our fRMI study also shows fast neural reorganization: ex-illiterates, who read at a rudimentary level, show nevertheless almost all the activation enhancements observed in early literates.

These literacy-dependent changes raise the question of how profound is the influence of literacy on the speech system, and, in particular, if literacy can modify the natural categories and representations of speech perception. The response is mitigated up to now. Literacy partly affect voicing categorization: in children aged 6 to 8 yrs vs. literate adults there is no significant age effect on categorical perception (*CP*, the correspondence between phoneme identification and phoneme discrimination performances), but boundary precision (*BP*, indexed by the steepness of the identification slope) increases with age and is correlated with reading level[210]. These data are coherent with our finding in literate vs. illiterate adults of a link between literacy and BP but not CP[211]. They contradict the strong view according to which speech categorization around school age develops through the acquisition of reading[212], but nevertheless suggest that literacy helps to finely tune phonological boundaries and hence improves the precision of phonemes labeling.

In the present project, we will further examine this question through perceptual categorization training studies in children around school age. In a previous study[213], we demonstrated that the French phonological boundary location for voicing categorization may be moved in healthy adults following five one-hour sessions of auditory identification training based on the perceptual fading procedure[214]. In order to investigate the impact of reading acquisition on the malleability of the phonological voicing categories, we plan to use a similar procedure in pre-reading children (3rd grade of kindergarten) as well as in beginning readers (from the 2nd grade of primary school on), who will be subdivided according to their reading level. Further studies will then aim at evaluating auditory training effects in children with developmental troubles in the acquisition of oral language (specific language impairments, SLI) and/or written language (dyslexia), for whom CP troubles have been reported[215-217]. Here, the expertise of **P2** (UG — De Houwer) will be useful in designing appropriate protocols.

The fact that spoken inputs activate brain regions involved in phonological processing like the planum temporale (PT) to a greater extent in literate than illiterate adults[184] is also coherent with the idea that literacy deeply invades the speech system. Being specific to spoken inputs, PT activation probably does not reflect direct on-line feedback from orthography to phonology. Yet, PT activation may be modulated by on-line feed-back from heteromodal regions involved in audio-visual integration of letters and phonemes (superior temporal sulcus/superior temporal gyrus). Indeed, PT does not respond to letters alone but is sensitive to the congruity between a phoneme and a simultaneous printed letter[218], an effect reduced in poor readers[219]. Alternatively, the PT enhancement may reflect on-line activation of metalinguistic representations that develop in the course of literacy acquisition[220-222]. A third possibility is that the nature of phonological representations has changed during reading acquisition: spelling knowledge may have turned them into partly integrated "phonographic" representations (e.g., Pattamadilok et al., 2010). To examine these possibilities, with both beginning reading children and illiterate vs. literate adults we will try to identify the behavioral correlates of the PT enhancement, and the link with the acquisition of metaphonological and orthographic representations. To this aim we will study speech identification and discrimination of spoken strings varying in discriminability (by consonant voicing, place and/or manner, and/or by vowel), manipulating in addition the degree of background or attention noise and the orthographic consistency of the strings. Indeed we know from previous studies that illiterate adults present recognition difficulties in challenging listening conditions[223]. We will also use a passive electrophysiological situation checking for audio-visual integration of letters and phonemes at two temporal windows, as beginning readers need the letter to be presented 200 ms earlier than the phoneme to display the integration that fluent readers show with simultaneous inputs[224].

Linked to this problem is the question of brain lateralization for speech in illiterates, which led up to now to conflicting results[225-227]. Based on the hypothesis that metaphonological and/or orthographic representations help literates to stabilize noisy phonological representations, we will examine how much lateralization for speech (and PT enhancement) depends on listening conditions, manipulating again strings discriminability, physical and attention noise, and orthographic consistency.

WP9 — Project Management

Lead Partner: P1 (ULB – Cleeremans)
Associated teams: —

WP9 is aimed at coordinating the planned research and will be undertaken by the project's coordinator, **P1** (ULB – Cleeremans). The corresponding network organization and management are described in full in **Form I** of this proposal.

References

1 Bar, M. (2009) Predictions: a universal principle in the operation of the human brain. *Philosophical Transactions of the Royal Society B* 364, 1181-1182

2 Friston, K. (2006) A free energy principle for the brain. *Journal of Physiology (Paris)* 100, 70-87

3 Clark, A. and Karmiloff-Smith, A. (1993) The cognizer's innards: A psychological and philosophical perspective on the development of thought. *Mind and Language* 8, 487-519

4 Dienes, Z. and Perner, J. (2007) The cold control theory of hypnosis. In *Hypnosis and conscious states: The cognitive neuroscience perspective* (Jamieson, G., ed), pp. 293-314, Oxford University Press

5 Koch, C. and Tsuchiya, N. (2007) Attention and consciousness: Two distinct brain processes. *Trends in Cognitive Sciences* 11, 16-22

6 Mitchell, C.J., *et al.* (2009) The propositional nature of human associative learning. *Behavioral and Brain Sciences* 32, 183-198

7 DeHouwer, J. (2009) The propositional approach to associative learning as alternative for association formation models. *Learning & Behavior* 37, 1-20

8 O'Reilly, R.C. and Munakata, Y. (2000) *Computational Explorations in Cognitive Neuroscience: Understanding the Mind by Simulating the Brain*. MIT Press

9 Sloman, S.A. (1996) The empirical case for two systems of reasoning. *Psychological Bulletin* 119, 3-22

10 Strack, F. and Deutsch, R. (2004) Reflective and impulsive determinants of social behavior. *Personality and Social Psychology Review* 8, 220-247

11 Lau, H. (2008) A higher-order Bayesian Decision Theory of consciousness. In *Models of brain and mind. Physical, computational and psychological approaches. Progress in Brain Research. Progress in Brain Research* (Banerjee, R. and Chakrabarti, B.K., eds), pp. 35-48, Elsevier

12 Metzinger, T. (2003) *Being No One: The self-model theory of subjectivity*. Bradford Books, MIT Press

13 Hofstadter, D.R. (2007) *I am a strange loop*. Basic Books

14 Pacherie, E. (2008) The phenomenology of action: A conceptual framework. *Cognition* 107, 179-217

15 Wolpert, D.M., *et al.* (2004) A unifying computational framework for motor control and social interaction. In *The neuroscience of social interaction* (Frith, C.D. and Wolpert, D.M., eds), pp. 305-322, Oxford University Press

16 Hassin, R.R., *et al.* (2005) *The new unconscious*. Oxford University Press

17 Smith, B.C. (2006) *Questions of taste: The philosophy of wine*. Oxford University Press

18 Blakemore, S.J., *et al.* (1999) Spatiotemporal prediction modulates the perception of self-produced stimuli. *Journal of Cognitive Neuroscience* 11, 551-559

19 Kandel, E.R. (2006) *In search of memory*. WW Norton

20 Szücs, D., *et al.* (2009) Motor conflict in Stroop tasks: Direct evidence from single-trial elctro-myography and electro-encephalography. *Neuroimage* 47, 1960-1973

21 Faivre, N. and Kouider, S. (2011) Multi-feature objects elicit nonconscious priming despite crowding. *Journal of Vision* 11, 1-10

22 Kouider, S., *et al.* (2011) Preference is biased by crowded facial expressions. *Psychological Science* 22, 184-189

23 Ramsoy, T.Z. and Overgaard, M. (2004) Introspection and subliminal perception. *Phenomenology and the Cognitive Sciences* 3, 1-23

24 Sandberg, K., *et al.* (2010) Measuring consciousness: Is one measure better than the other? *Consciousness and Cognition* 19, 1069-1078

25 Dienes, Z. and Seth, A. (2010) Gambling on the unconscious: A comparison of wagering and confidence as measures of awareness in an artificial grammar task. . *Consciousness and Cognition* 19, 674-681

26 Persaud, N., *et al.* (2007) Post-decision wagering objectively measures awareness. *Nature Neuroscience* 10, 257-261

27 Galvin, S.J., *et al.* (2003) Type 2 tasks in the theory of signal detectability: discrimination between correct and incorrect decisions. *Psychonomic Bulletin & Review* 10, 843-876

28 Jacoby, L.L. (1991) A process dissociation framework : Separating automatic from intentional uses of memory. *Journal of Memory and Language* 30, 513-541

29 Destrebecqz, A. and Cleeremans, A. (2001) Can sequence learning be implicit? New evidence with the Process Dissociation Procedure. *Psychonomic Bulletin & Review* 8, 343-350

30 Cohen, J. (1988) *Statistical power analysis for the behavioural sciences* Routledge Academic

31 Gilbert, C.D., *et al.* (2001) The neural basis of perceptual learning. *Neuron* 31, 681-697

32 Ramon, M., *et al.* (2011) The speed of personally familiar face recognition. *Perception*, 437-449

33 Calder, A., *et al.* (2011) *The Oxford Handbook of Face Perception.* Oxford University Press

34 Germine, A. (2011) A new selective developmental deficit: Impaired object recognition with normal face recognition. *Cortex* 47, 598-607

35 Kaufmann, J.M. and Schweinberger, S.R. (2011) The faces you remember: Caricaturing shape facilitates brain processes reflecting the acquisition of new face representations. *Biological Psychology*

36 Knappmeyer, B., *et al.* (2003) The use of facial motion and facial form during the processing of identity. *VIsion Research* 43, 1921-1936

37 Morrison, D.J. and Schyns, P.G. (2001) Usage of spatial scales for the categorization of faces, objects, and scenes. *Psychon Bull Rev.* 8, 454-469

38 Jiang, X., *et al.* (2008) Evaluation of a shape-based model of human face discrimination using FMRI and behavioral techniques. *Neuron* 50, 159-172

39 Haxby, J.V., *et al.* (2000) The distributed human neural system for face perception. *Trends in Cognitive Sciences* 46, 223-233

40 Ishai, A. (2008) Let's face it: it's a cortical network. *Neuroimage* 40, 415-419

41 Gobbini, I. and Haxby, J.V. (2001) Neural systems for recognition of familiar faces. *Neuropsychologia* 45, 32-41

42 Rossion, B., *et al.* (2001) How does the brain discriminate familiar and unfamiliar faces: a PET study of face categorical perception. *Journal of Cognitive Neuroscience* 13, 1019-1034

43 Rossion, B., *et al.* (2002) A defense of the subordinate-level expertise account of the N170 component. *Cognition* 85, 189-196

44 Rossion, B., *et al.* (2002) Expertise training with novel objects leads to face-like electrophysiological responses. *Psychological Science* 13, 250-257

45 Wilson, H.R. and Diaconescu, A. (2006) Learning alters local face space geometry. *Vision Research* 46, 4143-4151

46 Bruce, V. (1982) Changing faces: visual and non-visual coding processes in face recognition. *Br. J. Psychol.* 73, 105-116

47 Burton, A.M., *et al.* (1999) From pixels to people: a model of familiar face recognition. *Cognitive Science* 23, 1-31

48 Grill-Spector, K. and Malach, R. (2010) fMR Adaptation: A tool for studying the functional properties of cortical neurons. *Acta Psychologica* 107, 293-321

49 Preminger, S., *et al.* (2007) The effects of perceptual history on memory of visual objects. *Vision Research* 47, 965-973

50 Preminger, S., *et al.* (2009) Mapping dynamic memories of gradually changing objects. *Proc Natl Acad Sci U S A* 106, 5371-5376

51 Rossion, B. and MichelIn, C. (2011) An experienced-based holistic account of the other-race face effect. In *The Oxford Handbook of Face Perception* (Press, O.U., ed), pp. 215-244,

52 Peigneux, P. and Smith, C. (2010) Memory processing in relation to sleep. In *Principles and Practice of Sleep Medicine (5th Ed.)* (Kryger, M., ed), pp. 335-347, Elsevier
53 Sheth, B.R., *et al.* (2009) Does sleep really influence face recognition memory ? *PLoS One* 4
54 Wagner, U., *et al.* (2003) Signs of REM sleep dependent enhancement of implicit face memory: a repetition priming study. *Biol Psychol* 62, 197-210
55 Wagner, U., *et al.* (2007) The impact of post-learning sleep vs. wakefulness on recognition memory for faces with different facial expressions. *Neurobiol Learn Mem* 87, 679-687
56 Wagner, U., *et al.* (2003) Signs of REM sleep dependent enhancement of implicit face memory: a repetition priming study. *J. Born. Biol Psychol* 62, 197-210
57 Schmidt, C., *et al.* (2007) A time to think: circadian rhythms in human cognition. *Cogn Neuropsychol* 24, 755-789
58 de Heering, A. and Rossion, B. (2008) Prolonged visual experience in adulthood modulates holistic face perception. *PLOS One* 3
59 Beckers, T., *et al.* (2006) Reasoning rats: Forward blocking in Pavlovian animal conditioning is sensitive to constraints of causal inference. *Journal of Experimental Psychology: General* 135, 92-102
60 Blaisdell, A.P., *et al.* (2006) Causal reasoning in rats. *Science* 311, 1020-1022
61 Kamin, L.J. (1969) Selective association and conditioning. In *Fundamental Issues in Associative Learning* (Honing, N.J.M.W.K., ed), pp. 42-64, Dalhousie University Press
62 Rescorla, R.A. and Wagner, A.R. (1972) A theory of Pavlovian conditioning: variations in the effectiveness of reinforcement and nonreinforcement. In *Classical Conditioning II: Current Theory and Research* (Black, A.H. and Prokasy, W.F., eds), pp. 64-99, Appleton-Century-Crofts
63 Miller, R.R. and Matzel, L.D. (1988) The comparator hypothesis: A response rule for the expression of associations. In *The psychology of learning and motivation* (Bower, G.H., ed), pp. 51-92, Academic Press
64 Wheeler, D.S., *et al.* (2008) The effect of subadditive pretraining on blocking: Limits on generalization. *Learning & Behavior* 36, 341-351
65 Lu, H. and Yuille, A. (2008) Sequential causal learning in humans and rats. In *Proceedings of the 30th Annual Conference of the Cognitive Science Society* (Love, B.C., *et al.*, eds), pp. 185-190, R.R. Rojas
Cognitive Science Society
66 Beckers, T., *et al.* (2005) Outcome additivity and outcome maximality influence cue competition in human causal learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 31, 238-249
67 De Houwer, J. (2009) The propositional approach to associative learning as an alternative for association formation models. *Learning & Behavior* 37, 1-20
68 Haselgrove, M. (2010) Reasoning rats or associative animals? A common-element analysis of the effects of additive and subadditive pretraining on blocking. *Journal of Experimental Psychology: Animal Behavior Processes* 36, 296-306
69 Shanks, D.R. and Darby, R.J. (1998) Feature- and rule-based generalization in human associative learning. *Journal of Experimental Psychology: Animal Behavior Processes* 24, 405-415
70 Iordanova, M.D., *et al.* (2008) Configural learning without reinforcement: Integrated memories for correlates of what, where and when. *The Quarterly Journal of Experimental Psychology* 61, 1785-1792
71 Cools, R. (2011) Dopaminergic control of the striatum for high-level cognition. *Current Opninion in Neurobiology* 21, 402-407
72 Simms, V., *et al.* (2011, manuscript submitted) Additivity pretraining and cue competition effects: Developmental evidence for a reasoning-based account of causal learning.
73 Lovibond, P.F. (2003) Causal beliefs and conditioned responses: Retrospective revaluation induced by experience and by instruction. *Journal of Experimental Psychology: Learning, Memory, and Cognition* 29, 97-106
74 Garon, N., *et al.* (2008) Executive function in preschoolers: A review using and integrative framework. *Psychological Bulletin* 134, 1-50
75 Beck, S.R., *et al.* (2009) Relating developments in children's counterfactual thinking and executive functions. *Thinking and reasoning* 15, 337-354
76 Carlson, S.M. and Moses, L.J. (2001) Individual differences in inhibitory control and childrens' theory of mind. *Child Development* 72, 1032-1053
77 Livesey, E.J. and Boakes, R.A. (2004) Outcome additivity, elemental processing and blocking in human causality judgements. *Quarterly Journal of Experimental Psychology* 57B, 361-379
78 Cleeremans, A., *et al.* (1998) Implicit learning: News from the front. *Trends in Cognitive Sciences* 2, 406-416
79 De Houwer, J., *et al.* (2009) Implicit measures: A normative analysis and review. *Psychological Bulletin* 135, 347-368
80 Donald, M. (1993) Précis of the origins of the modern mind: Three stages in the evolution of culture and cognition. *Behavioral and Brain Sciences* 16, 737-791
81 Ikeda, K. and Morotomi, T. (1997) Reversed discriminatory responses of heart rate during human REM sleep. *Sleep* 20, 942-997
82 Wamsley, E.J. and Antrobus, J.S. (2009) The expression of trace conditioning during non-REM sleep and its relation to subjective experience. *Neurobiology of Learning and Memory* 92, 283-291
83 Maho, C., *et al.* (1999) Expression in paradoxical sleep of a conditioned heart rate response. *Neuroreport* 10, 3381-3385
84 Ikeda, K. and Morotomi, T. (1996) Classical conditioning during human NREM sleep and response transfer to wakefulness. *Sleep*, 72-74
85 Maho, C. and Bloch, V. (1992) Responses of hippocampal cells can be conditioned during paradoxical sleep. *Brain Research* 581, 115-122
86 Hennevin, E., *et al.* (2007) Neural representations during sleep: from sensory processing to memory traces. *Neurobiology of Learning and Memory* 87, 416-440
87 Cook, S.W. and Harris, R.E. (1937) The verbal conditioning of the galvanic skin reflex. *Journal of Experimental Psychology* 21, 202-210
88 De Houwer, J., *et al.* (2005) Further evidence for the role of mode-independent short-term associations in spatial Simon effects. *Perception & Psychophysics* 67, 659-666
89 Waszak, F., *et al.* (2008) Cross-talk of instructed and applied arbitrary visuomotor mappings. *Acta Psychologica* 127, 30-35
90 De Houwer, J., *et al.* (2005b-) Evidence for the role of higher-order reasoning processes in cue competition and other learning phenomena. *Learning & Behavior* 33, 239-249
91 Destrebecqz, A., *et al.* (2010) The influence of temporal factors on automatic priming and conscious expectancy in a simple reaction time task. *Quarterly Journal of Experimental Psychology* 63, 291-309
92 Jones, C.R., *et al.* (2010) Evaluative conditioning: The "how" question. In *Advances in experimental social psychology* (Zanna, M.P. and Olson, J.M., eds), pp. 205-255, Academic Press
93 DeHouwer, J. (2006) Using the implicit association test does not rule out an impact of conscious propositional knowledge on evaluative conditioning. *Learning and Motivation* 37, 176-187
94 Beckers, T., *et al.* (2009) Evaluative conditioning is insensitive to blocking. *Psychologica Belgica* 49, 41-57
95 Öhman, A. and Soares, J.J.F. (1998) Emotional conditioning to masked stimuli: Expectancies for aversive outcomes following non-recognized fear-relevant stimuli. *Journal of Experimental Psychology: General* 127, 69-82
96 Öhman, A. and Mineka, S. (2001) Fear, phobias and preparedness: Toward an evolved module of fear and fear learning. *Psychological Review* 108, 483-522
97 Mechias, M.L., *et al.* (2010) A meta-analysis of instructed fear studies: implications for conscious appraisal of threat. *Neuroimage* 49, 1760-1768
98 Phelps, E.A. and LeDoux, J.E. (2005) Contributions of the amygdala to emotion processing: from animal models to human behavior. *Neuron* 48, 175–187

99 Hartstra, E.*, et al.* (2011) The implementation of verbal instructions: An fMRI study. *Human Brain Mapping* 32, 1811-1824
100 Bradley, M.M. (2009) Natural selective attention: Orienting and emotion. *Psychophysiology* 46, 1-224
101 Miller, E.K. and Desimone, R. (1994) Parallel neuronal mechanisms for short-term memory. *Science* 263, 520-522
102 Grill-Spector, K. and Malach, R. (2001) fMR-adaptation: a tool for studying the functional properties of human cortical neurons. *Acta Psychologica* 107, 293-321
103 Shanks, D.R. and St. John, M.F. (1994) Characteristics of dissociable human learning systems. *Behavioral and Brain Sciences* 17, 367-447
104 Dixon, N.F. (1971) *Subliminal Perception: The nature of a controversy*. McGraw-Hill
105 Holender, D. (1986) Semantic activation without conscious activation in dichotic listening, parafoveal vision, and visual masking : A survey and appraisal. *Behavioral and Brain Sciences* 9, 1-23
106 Pessiglione, M.*, et al.* (2008) Subliminal instrumental conditioning demonstrated in the human brain. *Neuron* 59, 561-567
107 Chen, W.*, et al.* (2011) Unconscious structural knowledge of form-meaning connections. *Consciousness & Cognition*
108 Ziori, E. and Dienes, Z. (2008) How does prior knowledge affect implicit and explicit concept learning? *Quarterly Journal of Experimental Psychology* 61, 601-624
109 Leyton, M. (1992) *Symmetry, causality, mind*. MIT Press
110 Reber, R.*, et al.* (2004) Processing fluency and aesthetic pleasure: Is beauty in the perceiver's processing experience? . *Personality and Social Psychology Review* 8, 364-382
111 Cleeremans, A. and Dienes, Z. (2008) Computational models of implicit learning. In *Cambridge Handbook of Computational Psychology* (Sun, R., ed), pp. 396 - 421, Cambridge University Press
112 Marcus, G. (2001) *The Algebraic Mind: Integrating Connectionism and Cognitive Science*. MIT Press
113 Dienes, Z. and Longuet-Higgins, C. (2004) Can musical transformation be implicitly learned? *Cognitive Science* 28, 531-558
114 Kuhn, G. and Dienes, Z. (2005) Implicit learning of non-local musical rules: Implicitly learning more than chunks. *Journal of Experimental Psychology: Learning, Memory and Cognition* 31, 1417-1432
115 Custers, R. and Aarts, H. (2010) The unconscious will: how the pursuit of goals operates outside of conscious awareness. *Science* 329, 47-50
116 Demanet, J.*, et al.* (subm.) Dissociating top-down and bottom-up influences on intentional decisions within the medial prefrontal cortex.
117 Raichle, M.E.*, et al.* (2001) A default mode of brain function. *Proc Natl Acad Sci U S A* 98, 676-682
118 Brass, M. and Haggard, P. (2008) The what, when, whether model of intentional action. *Neuroscientist* 14, 319-325
119 Soon, C.S.*, et al.* (2008) Unconscious determinants of free decisions in the human brain. *Nat Neurosci* 11, 543-545
120 Destrebecqz, A.*, et al.* (2005) The neural correlates of implicit and explicit sequence learning: Interacting networks revealed by the process dissociation procedure. *Learn Mem* 12, 480-490
121 Wenke, D.*, et al.* (2010) Subliminal priming of actions influences sense of control over effects of action. *Cognition* 115, 26-38
122 Sandberg, K.*, et al.* (2010) Measuring consciousness: is one measure better than the other? *Conscious Cogn* 19, 1069-1078
123 Baumeister, R.F.*, et al.* (1998) Ego depletion: is the active self a limited resource? *J Pers Soc Psychol* 74, 1252-1265
124 Chee, M.W.*, et al.* (2008) Lapsing during sleep deprivation is associated with distributed changes in brain activation. *J Neurosci* 28, 5519-5528
125 Tomasi, D.*, et al.* (2009) Impairment of attentional networks after 1 night of sleep deprivation. *Cereb Cortex* 19, 233-240
126 Chee, M.W. and Chuah, L.Y. (2008) Functional neuroimaging insights into how sleep and sleep deprivation affect memory and cognition. *Curr Opin Neurol* 21, 417-423
127 Harrison, Y. and Horne, J.A. (2000) The impact of sleep deprivation on decision making: a review. *J Exp Psychol Appl* 6, 236-249
128 Venkatraman, V.*, et al.* (2007) Sleep deprivation elevates expectation of gains and attenuates response to losses following risky decisions. *Sleep* 30, 603-609
129 Vohs, K.D. and Schooler, J.W. (2008) The value of believing in free will - Encouraging a belief in determinism increases cheating. *Psychological Science* 19, 49-54
130 Baumeister, R.F.*, et al.* (2009) Prosocial benefits of feeling free: disbelief in free will increases aggression and reduces helpfulness. *Pers Soc Psychol Bull* 35, 260-268
131 Rigoni, D.*, et al.* (2011) Inducing disbelief in free will alters brain correlates of preconscious motor preparation: the brain minds whether we believe in free will or not. *Psychol Sci* 22, 613-618
132 Wickens, J.R.*, et al.* (2007) Dopaminergic mechanisms in actions and habits. *J. Neurosci.* 27, 8181-8183
133 Wenke, D.*, et al.* (2010) Subliminal priming of actions influences sense of control over effects of action. *Cognition* 115, 26-38
134 Elsner, B. and Hommel, B. (2001) Effect anticipation and action control. *J. Exp. Psychol. Hum. Percept. Perform.* 27, 229-240
135 Cleeremans, A. (2011) The radical plasticity thesis: How the brain learns to be conscious. *Frontiers in Psychology* 2, 1-12
136 Cleeremans, A. (2008) Consciousness: The radical plasticity thesis. *Progress in Brain Research* 168, 19-33
137 Marcel, A.J. (1983) Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psychology* 15, 197-237
138 Del Cul, A.*, et al.* (2007) Brain dynamics underlying the nonlinear threshold for access to consciousness. *PloS Biology* 5, e260
139 Archambault, A.*, et al.* (1999) Blind to object changes: When learning the same object at different levels of categorization modifies its perception. *Psychological Science* 10, 249-255
140 Dehaene, S.*, et al.* (1998) Imaging unconscious semantic priming. *Nature* 595-600
141 Shapiro, K.L.*, et al.* (1997) The Attentional Blink. *Trends in Cognitive Sciences* 1, 291-295
142 Bentin, S.*, et al.* (1996) Electrophysiological studies of face perception in humans. *Journal of Cognitive Neuroscience* 8, 551-565
143 Schwiedrzik, C.M.*, et al.* (2009) Sensitivity and perceptual awareness increase with practice in metacontrast masking. *Journal of Vision* 9, 11-18
144 Seibel, R. (1963) Discrimination reaction time for a 1,023 alternative task. *Journal of Experimental Psychology* 66, 215-226
145 Cohen, A.*, et al.* (1990) On the control of automatic processes: A parallel distributed processing account of the Stroop effect. *Psychological Review* 97, 332-361
146 Viviani, P. and Stucchi, N. (1989) The effect of movement velocity on form perception: Geometric illusions in dynamic displays. *Perception and Psychophysics* 46, 266-274
147 Cleeremans, A. and McClelland, J.L. (1991) Learning the structure of event sequences. *Journal of Experimental Psychology : General* 120, 235-253
148 Cleeremans, A.*, et al.* (2007) Consciousness and metarepresentation: A computational sketch. *Neural Networks* 20, 1032-1039
149 Pasquali, A.*, et al.* (2010) Know thyself: Metacognitive networks and measures of consciousness. *Cognition* 117, 182-190
150 Rosenthal, D. (1997) A theory of consciousness. In *The Nature of Consciousness: Philosophical Debates* (Block, N.*, et al.*, eds), MIT Press
151 Lau, H. and Rosenthal, D. (2011) Empirical support for higher-order theories of consciousness. *Trends in Cognitive Science* 15, 365-373
152 Karmiloff-Smith, A. (1992) *Beyond modularity : A developmental perspective on cognitive science*. MIT Press
153 Wolpert, D.M. (1997) Computational approaches to motor control. *Trends in Cognitive Sciences* 1, 209-216

154 Wolpert, D.M., *et al.* (1995) An internal model for sensorimotor integration. *Science* 269, 1180-1182
155 Maniscalco, B. and Lau, H. (2010) Comparing signal detection models of perceptual decision confidence. *Journal of Vision* 10, 213
156 Pleskac, T.J. and Busemeyer, J. (2010) Two-stage dynamic signal detection: A theory of confidence, choice, and response time. *Psychological Review* 117, 864-901
157 Lau, H. (2010) Comparing different signal processing architectures that support conscious reports. In *14th annual meeting of the Association for the Scientific Study of Consciousness*
158 Rounis, E., *et al.* (2010) Theta-burst transcranial magnetic stimulation to the prefrontal cortex impairs metacognitive visual awareness. *Cognitive Neuroscience* 1, 165-175
159 Stam, H. and Spanos, N. (1987) Hypnotic analgesia, placebo analgesia, and ischemic pain: The effect of contextual variables. *Journal of Abnormal Psychology* 96, 313-320
160 Fan, J., *et al.* (2002) Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience* 14, 340-347
161 Perruchet, P., *et al.* (2006) Dissociating the effects of automatic activation and explicit expectancy on reaction times in a simple associative learning task. *J Exp Psychol Learn* 32, 955-965
162 Dehaene, S., *et al.* (2006) Conscious, preconscious, and subliminal processing: A testable taxonomy. *Trends in Cognitive Sciences* 10, 204-211
163 Lamme, V.A.F. (2010) How neuroscience will change our view on consciousness. *Cognitive Neuroscience* 1, 204-220
164 Fleming, S.M., *et al.* (2010) Relating instrospective accuracy to individual differences in brain structure. *Science* 329, 1541-1543
165 Bechara, A., *et al.* (1994) Insensitivity to future consequences following damade to human prefrontal cortex. *Cognition* 50, 7-15
166 Goodie, A.S. (2005) The role of perceived confidence and overconfidence in pathological gambling. *Journal of Gambling Studies* 21, 481-502
167 Lakey, C.E., *et al.* (2007) Frequent card playing and pathological gambling: The utility of the Georgia Gambling Task and the Iowa Gambling Task for predicting pathology. *Journal of Gambling Studies* 23
168 Breen, R.B. and Frank, M.L. (1993) The effects of statistical fluctuations and perceived status of a competitor on the illusion of control in experienced gamblers. *Journal of Gambling Studies* 9, 265-276
169 Toneatto, T. (1999) Cognitive psychopathology of problem gambling. *Substance use and misuse* 34, 1593-1604
170 Maguire, E.A., *et al.* (2000) Navigation-related structural change in the hippocampi of taxi drivers. *Proceedings of the National Academy of Sciences of the U.S.A.* 10, 1073
171 Elbert, T., *et al.* (1995) Increased cortical representation of the fingers of the left hand in string players. *Science* 270, 305-307
172 Kreiman, G., *et al.* (2002) Single-neuron correlates of subjective vision in the human medial temporal lobe. *Proceedings of the National Academy of Sciences of the U.S.A.* 99
173 Farah, M.J. (1998) Why does the somatosensory homonculus have hands next to face and feet next to genitals: A hypothesis. *Neural Computation* 10, 1983-1985
174 Barrett, A.B. and Seth, A.K. (2011) Practical measures of integrated information for time series data. *PloS Computational Biology* 7, e1001052
175 Libet, B., *et al.* (1983) Time of conscious intention to act in relation to onset of cerebral activity (readiness-potential). The unconscious initiation of a freely voluntary act. *Brain* 106
176 Miller, J., *et al.* (2011) Effects of clock monitoring on electroencephalographic activity: is unconscious movement initiation an artefact of the clock? *Psychological Science* 22, 103-109
177 Lau, H. (2009) Volition and the functions of consciousness. In *Cognitive Neurosciences IV* (Gazzaniga, M., ed), pp. 1191-1201, MIT Press
178 Lau, H., *et al.* (2004) Attention to intention. *Science* 303, 1208-1210
179 Haggard, P. and Eimer, M. (1999) On the relation between brain potentials and the awareness of voluntary movements. *Experimental Brain Research* 126, 128-133
180 Soon, C.S., *et al.* (2008) Unconscious determinants of free decisions in the human brain. *Nature Neuroscience* 11, 543-545
181 Geary, D.C. (1995) Reflections of evolution and culture in children's cognition: implications for mathematical development and instruction. *American Psychologist* 50, 24-37
182 Cohen, L., *et al.* (2000) The visual word form area: Spatial and temporal characterization of an initial stage of reading in normal subjects and posterior split-brain patients. *Brain* 123, 291-307
183 Dehaene, S. and Cohen, L. (2011) The unique role of the visual word form area in reading. *Trends in Cognitive Sciences* 15, 254-262
184 Dehaene, S., *et al.* (2010) How learning to read changes the cortical networks for vision and language. *Science* 330, 1359-1354
185 Dehaene, S. and Cohen, L. (2007) Cultural recycling of cortical maps. *Neuron* 56, 384-398
186 Young, A.W., *et al.* (1987) Configurational information in face perception. *Perception* 16, 747-759
187 Tanaka, J.W. and Farah, M.J. (1993) Parts and wholes in face recognition. *Quarterly Journal of Experimental Psychology* 46A, 225-245
188 Wong, A.C.N., *et al.* (2011) Holistic Processing of Words Modulated by Reading Experience. *PlosOne* 6, 1-7
189 Yin, R.K. (1969) Looking at upide-down faces. *Journal of Experimental Psychology* 81, 141-145
190 Rayner, K. (1975) The perceptual span and peripheral cues in reading. *Cognitive Psychology* 7, 65-81
191 Rayner, K. (1998) Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin* 124, 372-422
192 Van Belle, G., *et al.* (2010) Whole not hole: expert face recognition requires holistic perception. *Neuropsychologia* 48, 2609-2620
193 Van Belle, G., *et al.* (2010) Face inversion impairs holistic perception: Evidence from gaze-contingent stimulation. *Journal of Vision* 5, 1-13
194 Shaywitz, S.E. and Shaywitz, B.A. (2005) Dyslexia (specific reading disability). *Biological Psychiatry* 57, 1301-1309
195 Shaywitz, B.A., *et al.* (2004) Development of left occipitotemporal systems for skilled reading in children after a phonologically-based intervention. *Biological Psychiatry* 55, 926-933
196 Simos, P.G., *et al.* (2002) Dyslexia-specific brain activation profile becomes normal following successful remedial training. *Neurology* 58, 1203-1213
197 Hillger, L.A. and Koenig, O. (1991) Separable mechanisms in face processing: Evidence from hemispheric specialization. *Journal of Cognitive Neuroscience* 3, 42-58
198 Gilbert, C. and Bakan, P. (1973) Visual asymmetry in perception of faces. *Neuropsychologia* 11, 355–362
199 Rossion, B., *et al.* (2003) Early lateralization and orientation tuning for face, word and object processing in the visual cortex. *NeuroImage* 20, 1609-1624
200 Rossion, B., *et al.* (2004) Visual expertise with nonface objects leads to competition with the early perceptual processing of faces in the human occipitotemporal cortex. *PNAS* 101, 14521-14526
201 Barton, J., *et al.* (2010) Reading words, seeing style: the neuropsychology of word, font and handwriting perception. *Neuropsychologia* 48, 3869-3077
202 Behrmann, M. and Avidan, G. (2005) Congenital prosopagnosia: Face-blind from birth. *Trends in Cognitive Science* 9, 180-187
203 Russell, R., *et al.* (2009) Super-recognizers: people with extraordinary face recognition ability. *Psychon Bull Rev.* 16, 252-257
204 Hashimoto, R. and Sakai, K.L. (2004) Learning letters in adulthood: Direct visualization of cortical plasticity for forming a new link between orthography and phonology. *Neuron* 42, 311-322
205 Bolger, D.J., *et al.* (2005) Cross-cultural effect on the brain revisited: Universal structures plus writing system variations. *Human Brain Mapping* 25, 92-104

206 Reich, L., *et al.* (2011) A Ventral Visual Stream Reading Center Independent of Visual Experience. *Current Biology* 21
207 Ventura, P., *et al.* (2004) The locus of the orthographic consistency effect in auditory word recognition. *Language and Cognitive Processes* 19, 57-95 URLJ: http://www tandf co uk/journals/ /01690965 html
208 Pattamadilok, C., *et al.* (2010) Auditory word serial recall benefits from orthographic dissimilarity. *Language and Speech,* 53, 321-341.
209 Ventura, P., *et al.* (2007) The development of the orthographic consistency effect in speech recognition: from sublexical to lexical involvement. *Cognition* 105, 547-576
210 Hoonhorst, I., *et al.* (2011) Categorical perception of voicing, colors and facial expressions: A developmental study. *Speech Communication* 53, 417-430
211 Serniclaes, W., *et al.* (2005) Categorical perception of speech sounds in illiterate adults. *Cognition* 98, B35-B44
212 Burnham, D.K. (2003) Language specific speech perception and the onset of reading. *Reading and Writing* 16, 573-609
213 Collet, G., *et al.* (submitted) Do French speakers adopt a new phonological boundary after identification training? . *Journal of the American Academy of Audiology*
214 Jamieson, D.G. and Morosan, D.E. (1986) Training nonnative speech contrasts in adults: acquisition of the English /delta/ - /theta/ contrast by francophones. *Percept. Psychophys.* 40, 205-215
215 Manis, F. and Keating, P. (2004) Speech perception in dyslexic children with and without language impairments. *UCLA Working Papers in Phonetics* 103, 30-47
216 Serniclaes, W., *et al.* (2001) Perceptual categorization of speech sounds in dyslexics. *J. Speech Lang. Hear. R.* 44, 384-399
217 Serniclaes, W., *et al.* (2004) Allophonic mode of speech perception in dyslexia. *J. Exp. Child Psychol.* 87, 336-361
218 van Atteveldt, N., *et al.* (2004) Integration of letters and speech sounds in the human brain. *Neuron* 43, 271-282
219 Blau, V., *et al.* (2010) Deviant processing of letters and speech sounds as proximate cause of reading failure: a functional magnetic resonance imaging study of dyslexic children. *Brain* 133, 868-879
220 Morais, J., *et al.* (1987) The relationships between segmental analysis and alphabetic literacy: an interactive view. *Cahiers de Psychologie Cognitive* 7, 415-438
221 Morais, J., *et al.* (1986) Literacy training and speech segmentation. *Cognition* 24, 45-64
222 Morais, J., *et al.* (1979) Does awareness of speech as a sequence of phones arise spontaneously? *Cognition* 7, 323-331
223 Morais, J., *et al.* (1987) The effects of literacy on the recognition of dichotic words. *Q J Exp Psychol A* 39, 451-465
224 Froyen, D.J.W., *et al.* (2009) The long road to automation: Neurocognitive development of letter-speech sound processing. *Journal of Cognitive Neuroscience* 21, 567-580
225 Castro, S.L. and Morais, J. (1987) Ear differences in illiterates. *Neuropsychologia* 25, 409-417
226 Damasio, H., *et al.* (1979) Reversal of ear advantage for phonetically similar words in illiterates. *Journal of Clinical Neuropsychology* 1, 331-338
227 Tzavaras, A., *et al.* (1981) Literacy and hemispheric specialization for language: Digit dichotic listening in illiterates. *Neuropsychologia* 19, 565-570

FORM E: PARTICIPATION OF THE PARTNERS IN THE DIFFERENT WORK PACKAGES

	PARTNER	WP1	WP2	WP3	WP4	WP5	WP6	WP7	WP8	WP9
P1	Name : CLEEREMANS Institution : ULB	x	x	x	x	x	x	**Head**	**Head**	**Head**
P2	Name : DE HOUWER Institution : UG		x	**Head**					x	
P3	Name : BRASS Institution : UG			x		**Head**	x	x		
P4	Name : BECKERS Institution : KUL		**Head**	x	x					
P5	Name : ROSSION Institution : UCL	**Head**						x	x	
INT1	Name : HAGGARD Institution : UCLondon			x		x	**Head**	x		
INT2	Name : DIENES Institution : USussex				**Head**			x		

FORM F: MAIN SKILLS OF THE PARTNERS

Describe the main skills of each of the partners in relation to the proposal (15 lines maximum per partner).
Delete not used lines.

P1 - Name : Axel CLEEREMANS
Institution : Université Libre de Bruxelles
Main Skills :
Axel Cleeremans is heading the Consciousness, Cognition, and Computation Group at the Université Libre de Bruxelles (ULB), and, for the purposes of this project, is representing all four teams active in the domain of cognitive psychology at the ULB (LCLD, head: Pr. Alain Content; UR2NG, head: Pr. Philippe Peigneux; UNESCOG, head: Pr. Régine Kolinsky). Cleeremans own's research interests are focused on understanding the differences between conscious and unconscious processing. This undertaking involves theoretical work aimed at developing a learning-based account of consciousness, empirical work in different domains ranging from implicit learning to hypnosis, as well as computational modelling work.

P2 - Name : Jan DE HOUWER
Institution : Universiteit Gent
Main Skills :
The research of Prof. De Houwer concerns the manner in which automatic preferences are learned and can be measured. He focuses on the role of stimulus pairings and high-level processes. This research has led to theoretical, conceptual, and empirical contributions concerning evaluative and non-evaluative types of learning. With regard to the measurement of preferences, he developed new reaction time measures and examined the processes underlying various measures.

P3 - Name : Marcel BRASS
Institution : Universiteit Gent
Main Skills :
Dr. Brass is heading the group motor and cognitive control. He has extensive experience in the domain of brain imaging and prefrontal cortex functioning. He is doing research on cognitive control, motor control, intentional action and the unconscious processes.

P4 - Name : Tom BECKERS
Institution : Katholieke Universiteit Leuven
Main Skills :
Fundamental processes of learning and conditioning in infant and adult humans and in rodents, using behavioural, neurobiological, and computational techniques. Cue competition in causal learning and conditioning. The role of learning and conditioning in psychopathology (particularly fear and addiction). Stimulus-response compatibility tasks. Approach-avoidance tendencies in psychopathology.

P5 - Name : Bruno ROSSION
Institution : Université Catholique de Louvain
Bruno Rossion's main research interest is to understand how does the human brain categorize objects of the visual world. He has a particular interest in the visual perception and recognition of a fascinating category of objects: faces.The face is undoubtedly a 'special' type of stimulus, with a long evolutionary history and a critical role in humans for social communication.To clarify the neuro-functional mechanisms of face perception, Rossion strongly believes in the combination of data from various methods. The research involves using neuroimaging (PET, fMRI), EEG and ERP, eye movement recordings, and behavioral studies in normal adults and children, as well as in brain-damaged people suffering from face recognition deficits (acquired prosopagnosia).

INT1 - Name : Patrick HAGGARD
Institution : University College London
Main Skills : Pr. Haggard has a long research track-record in the relationship between consciousness and voluntary action, and ranks amongst the highest-profile groups in Europe on this question. He leads a

group of 12 researchers and has extensive expertise on the processes that subtend volition, action, and the sense of conscious agency.

INT2 - Name : Zoltan DIENES
Institution : University of Sussex
Main Skills : Pr. Zoltan Dienes is internationally renowned for his work on the distinction between conscious and unconscious processes. He draws on philosophy, experimental psychology, computational modeling and, more recently, neuroscience, with no discipline taking precedence per se, to find out interesting principles characterizing unconscious processes. Dienes directs a research group at the University of Sussex, and is also associated with the prestigious Sackler Center for Consciousness Science.

FORM G: ADDED VALUE OF THE INTERNATIONAL PARTNERS

(25 lines per partner maximum)
Justify the added value of the collaboration with the international partner for the network as a whole.

Pr. **Patrick Haggard** (**INT1**) has a long research track-record in the relationship between consciousness and voluntary action, and ranks amongst the highest-profile groups in Europe on this question. His focus adds a novel and highly functional dimension to the program: Previous studies of the relations between consciousness and learning have largely considered whether people are aware of patterns in external stimuli. In contrast, Haggard's work deals with the awareness of one's own actions.

Second, his work brings a focus on instrumental learning and instrumental action: humans and animals not only perceive events and stimuli in the outside world, but also produce such events through their own purposive action. Instrumental learning studies in animals have investigated the rules underlying such behaviour, but have never satisfactorily grappled with the role of consciousness in such learning, due to the great difficulty of studying consciousness in animals. By combining traditions of human subjective report with instrumental learning, Haggard's research has shown that acting on the world produces a particular range of conscious experiences of cause-effect association, termed 'sense of agency'. By his work on psychophysical and neurophysiological methods of studying sense of agency, Haggard has extended the links between consciousness and learning research, for example in studying the temporal binding effect that produces subjective compression of the time interval between voluntary actions and their outcomes.

Third, Haggard participates in several important European and international research networks, including institutional collaborations with German, Italian, Dutch and other universities. This connectedness offers a wider focus and set of opportunities for all the members of the IUAP network. He has extensive involvement with ESF, Max Planck Society and other funders. He has 188 publications, and an H index of 37, and he leads a group of 14 researchers, with funding from ESRC, Wellcome Trust, Leverhulme Trust, EU FP7, Fyssen Foundation, and Bial Foundation among others.

Pr. **Zoltan Dienes** (**INT2**) is internationally renowned for his work on the distinction between conscious and unconscious processes. He draws on philosophy, experimental psychology, computational modeling and, more recently, neuroscience, with no discipline taking precedence per se, to find out interesting principles characterizing unconscious processes. Dienes directs a research group at the University of Sussex, and is also associated with the prestigious Sackler Center for Consciousness Science. He is currently organizing ASSC16, the 16th annual meeting of the Association for the Scientific Study of Consciousness. He has recently authored a book dedicated to Bayesian approaches to statistical inference (Palgrave Macmillan, 2008).

Dienes's wide-ranging expertise and knowledge in different domains relevant to the goals of the project will be highly beneficial to the partners. His expertise in implicit learning, hypnosis and subliminal perception will be particularly valuable. Dienes has 88 publications and an H index of 24.

Dienes has extensive international connections, collaborating with Joseph Perner at the University of Salzburg and with the Qiufang Fu and others at the Chinese Academy of Sciences, where he is yearly invited to lecture.

FORM H: YOUNG EMERGING TEAMS

Partner 4 is a young K.U.Leuven team led by Prof. Tom Beckers. Before being appointed an associate professor of research (BOFZAP) at K.U.Leuven in 2010, Tom Beckers was assistant professor at the University of Amsterdam, where he established an NWO-funded research team looking at psychological mechanisms of human fear conditioning. Upon joining K.U.Leuven, he was awarded Centre of Excellence status in a consortium with six other K.U.Leuven professors. He successfully applied for an FWO research grant to establish an animal conditioning lab, which is in operation since Fall 2011, to pursue research along the lines of ground-breaking animal learning research he did in the labs of Prof. Ralph Miller (Binghamton University, NY, USA) and Prof. Aaron Blaisdell (UCLA, CA, USA). He is also continuing work on processes of causal learning in humans, including children. Funding of the present network will ensure that the team that he leads will immediately be linked to the most prominent teams in the psychology of learning and plasticity in Belgium.

The team that Beckers heads includes dr. Bram Vervliet, who joined Tom Beckers upon his move from Amsterdam to Leuven as a senior scientist. Dr. Vervliet is internationally renowned for his work on generalization processes in human causal learning and fear conditioning. Another member is Dr. Bridget McConnell, an FWO-funded postdoctoral fellow coming from the Miller lab at Binghamton University who is an expert on animal learning. For the present application, the core team is supplemented by Prof. Frank Baeyens, a more senior professor and member of the same Centre of Excellence, who has specific expertise on topics that are relevant for the network, such as evaluative conditioning and the role of contingency awareness in human associative learning.

FORM I: NETWORK ORGANISATION AND MANAGEMENT

COOL is intended and organized as a **full cooperation between the partners**: progress in attaining the project's objectives is indeed only possible to the extent that the partners actually collaborate. As mentioned in the summary, the different partners of this IAP project already know each other and each other's work very well, and some have already initiated active collaborations over the past couple of years.

Coordinating this project entails collaborative efforts along four main dimensions: (1) administration, (2) scientific coordination, (3) dissemination of knowledge, and (4) training. We detail our proposals for each of these aspects below.

1 — Administration

The promoter will coordinate and synchronize the tasks for this project, as outlined below. The project's coordinator, Axel Cleeremans, will take responsibility for coordinating and managing all aspects of the program, including production of the yearly reports. Full secretarial support will be provided, thus allowing for smooth communication with the different partners. Coordination meetings involving the main promoters are also scheduled to take place at least once yearly, on the occasion of one of the scientific meetings (see below).

Cleeremans has substantial expertise managing large projects and teams. His experience in managerial positions includes acting as the president of the Belgian Association for Psychological Sciences (2005-2008) and as the president of the European Society for Cognitive Psychology (2009-2010). Cleeremans has also long been a member of the board of the Association for the Scientific Study of Consciousness, and has organized several large-scale international meetings in Belgium and elsewhere. Further, Cleeremans has been involved in several European Commission projects (with the RPTN and the NEST programs), and is currently managing COST Action BM0605 titled "Consciousness: A transdisciplinary, integrated approach", which involves coordinating the research activities of about 20 european groups in domains ranging from philosophy to the neurosciences. Locally, Cleeremans is also currently heading a Concerted Research Action (Project 06/11 – 342) for the French-speaking Community of Belgium. This project involves 6 teams from the Université Libre de Bruxelles, representing about 70 scientists, and is dedicated to "Culturally modified organisms: What it means to be human in age of culture". The managerial aspects of this project will benefit from the assistance of Ms. Angélique Bernacki, who holds a full-time research administration position in the department, as well as from the support from the Research Administration Department of the Université Libre de Bruxelles.

2. Scientific coordination

In addition to **regular communication** through both various electronic (email, web site; see below) and non-electronic means (fax and telephone), the scientific personnel of the different groups will meet once yearly, at the Université Libre de Bruxelles, to present data, and to discuss progress. The following schedule of meetings is proposed over the full five-years period covered by the program:

An initial meeting will be organized within the first 2 months to review the current status of the research conducted in the laboratories of each partner, to coordinate the tasks of the partners, and also to define which specific tasks should be carried out by each partner in priority.

Four coordination meetings to address administrative, methodological as well as scientific problems will be organized at the end of months 6, 18, 30, and 42. These meetings will be open to all participating scientific personnel, and will be held at the different host institutions (ULB, UCL, KUL and UGhent). They will offer the opportunity for the main promoters to coordinate their efforts, and for all to present their latest work in an informal atmosphere that promotes the exchange of ideas. The two international partners will of course be invited to take part in these meetings.

Four annual meetings will be organized at the end of months 12, 24, 36, 48. Selected scientific presentations from the different partners will offer the opportunity for each to present their results in a more formal manner. Members of the follow-up committee and international invited specialists will participate in these meetings to discuss ongoing work conducted by the network and to suggest new directions of research. When appropriate, efforts will be made to publish the proceedings of these annual meetings, for instance in the form of a book or a special issue of a journal.

One final-term meeting will be organized at the beginning of month 60. Conclusions about which workpackages were successfully achieved, as well as discussion of the possibilities for the further continuation of the collaboration will be submitted.

Furthermore, a copy of all the **raw data** and **experimental protocols** will be archived in a secured room at the Université Libre de Bruxelles and will be made available to all partners.

3. Dissemination of knowledge

Dissemination of the network's results, both among partners as well as to the general scientific public, will be achieved in the following ways:

A **web site** containing general information about the project, as well as several databases, will be set up at the Université Libre de Bruxelles so as to (1) promote up-to-date availability of information to all partners, (2) offer an archived record of the network's activity, (3) increase the visibility of the network in the eyes of the larger scientific community. This latter aspect is particularly important for the emergence of new potential collaborations and for attracting new advanced students in the institutions of the partners. The databases that will be made available on this website include:

A **joint bibliographic database** of all relevant publications in the domain. This database will be accessible to all partners through the web site. Each partner will be able to both consult and amend the database.

An **archive of preprints and reprints** of the scientific articles produced by the partners, either individually or in the context of the network. This database will offer, whenever possible (i.e., considering current copyright laws), the full text of all relevant publications to the general scientific public.

A **schedule** and **archive** of all network-related meetings, as well as links to relevant international meetings.

A **listing** of relevant links to other relevant web sites in the domain.

Publication of results in relevant and highly ranked journals

Presentation of early data at various scientific meetings held around the world. All partners, and particularly Ph.D. students, will be encouraged to participate in as many relevant international meetings as financially possible.

4. Training

Training of young scientists is a **central component of this project** that all partners view as very important. In this respect, all graduate students coming from the different research units involved in the project will have the opportunity to participate fully in the scientific activities of the network. It is hoped that most of the planned research can be carried out by actively involving graduate students from one team into the research of another. Opportunities for further training will also be actively pursued; for instance through participation in training seminars organized in Brussels in the fMRI and MEG brain imaging units. Finally, all partners will be invited to take part in the seminar series and scientific meetings they regularly organize.

FORM J: BUDGET (global distribution per partner)

(in EURO, without decimals)
The detailed distribution per partner is given in Section II - form S

	Name Partner	Institution	Budget
P1	CLEEREMANS, AXEL	ULB	1 321.608
P2	DE HOUWER, JAN	UGent	610.334
P3	BRASS, MARCEL	UGent	588.175
P4	BECKERS, TOM	KUL	499.900
P5	ROSSION, BRUNO	UCL	500.000
INT1*	HAGGARD, PATRICK	UCLondon	
INT2*	DIENES, ZOLTAN	USussex	

* The budget for the international partner is the budget attributed by the IAP-programme only (without the 50% contribution of the international partner and with a maximum of 1[illegible]0.000 EUR per proposal).

Form K: To be filled in only in the case of proposals from networks funded during earlier phases of the IAP programme

a) If partners or teams in the present proposal have already participated in previous IAP-networks, mention their names, the phases of the IAP-programme (I, II, III, IV, V, VI) and the titles of the networks.

Not applicable.

b) Justify participation in phase VII in accordance with the results of the ex-post evaluation phase VI and, where applicable, with the network's re-organisation and reorientation of its research direction (1 page maximum).

Not applicable

BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 ▪ Fax +32 2 230 59 12
www.belspo.be

Interuniversity Attraction Poles (IAP)
Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION II

Information on the partners

To be filled in by each network partner
including the international partner

Attention: Before filling in this submission form, please read carefully the information document of the call

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words): **Mechanisms of conscious and unconscious learning**
Proposal's acronym: **COOL**
Name of the partner: **Cleeremans, Axel** Institution: **Université Libre de Bruxelles**
Code (Reserved for BELSPO) :

FORM L: PARTNER CONTACT DETAILS

PARTNER N° (consult the list in Section I - Form A)*: **P1**

- Family Name : Cleeremans
- First Name : Axel
- Title (Prof., Dr., …) : Professor
- Institution : Université Libre de Bruxelles
- Institution's abbreviation : ULB
- Faculty/Department : Faculty of Psychology and Education sciences
- Research Unit : Consciousness, Cognition & Computation Group
- Road/Street, n° : Avenue F. Roosevelt, 50 CP191
- Postal Code : 1050
- Town/City : Brussels
- Country : Belgium
- Tel : 02 650 32 96
- Tel secretariat : 02 650 26 31
- Fax : 02 650 22 09
- E-mail : axcleer@ulb.ac.be
- Website : srsc.ulb.ac.be/axcWWW/axc.html

* For Belgian partners : P1 to P16
For International partners : INT1 to INT4

FORM M: STAFF MEMBERS OF THE PARTNER TEAM (by profile)

Indicate the number of currently working staff members in the research team of the partner

Profile	Number
Professor	11
Senior scientist	7
Post-doc	6
PhD student	28
Researcher without PhD	0
Technician	0
Secretary	1
Other	12
TOTAL	**65**

FORM N: STAFF MEMBERS WORKING ON THE PROJECT

1. Name : **Cleeremans, Axel, head, Consciousness, Cognition & Computation Group (CO3)**
   Profile : Research Director with the F.N.R.S., Professor
   Skills : Expertise in consciousness, learning, and computational modeling

2. Name : **Kolinsky, Régine, head, Cognitive Neuroscience Unit (UNESCOG)**
   Profile : Research Director with the F.N.R.S., Professor
   Skills : The research of Prof. Kolinsky mainly concerns the impact of literacy acquisition on other processing systems. She largely contributed to reveal the consequences of literacy by identifying, in literates, the behavioral effects of spelling knowledge on speech recognition and memory, and offered the first evidence, through fMRI and behavioral comparisons between literate and illiterate adults, that literacy deeply impacts on brain responses to spoken language and nonlinguistic vision.

3. Name : **Content, Alain, head, Cognition, Language and Development Laboratory (LCLD)**
   Profile : Professor
   Skills : Prof. Content's research concerns both visual and auditory word recognition, and more specifically the nature of sub-lexical units that intervene in perceptual processing. Current projects concern more specifically orthographic coding in multisyllabic letter strings, and the identification of the factors determining the internal structure of orthographic representations, including explicit learning and incidental exposition to texts through reading activity. Expertise in Psycholinguistics, literacy, reading acquisition

4. Name : **Peigneux, Philippe, head, Research Unit in Neuropsychology and Neuroimaging (UR2NF)**
   Profile : Professor
   Skills : The research of Prof. Peigneux mostly concerns the relationships between, sleep, biological rhythms, learning and memory consolidation, using behavioral and neuroimaging techniques. His research has contributed to evidence the neural mechanisms by which recently learned information is consolidated outside of the learning episode (offline) during post-training wake and sleep periods, as well as the complex interactions between circadian and sleep pressure-related cerebral mechanisms underlying variations in cognitive performance throughout the day. Expertise in learning and memory, sleep and cognitive processes, neuroimaging (PET, fMRI, EEG, MEG), neuropsychology

5. Name : Leybaert, Jacqueline (LCLD)
   Profile : Professor
   Skills : Psycholinguistics, speech perception, audio-visual interactions in perception

6. Name : Mousty, Philippe (LCLD)
   Profile : Senior scientist
   Skills : Psycholinguistics, speech perception, audio-visual interactions in perception

7. Name : Destrebecqz, Arnaud (CO3)
   Profile : Senior scientist
   Skills : Expertise in implicit learning and cognitive development. Head of babylab (ulbabylab.ac.be)

8. Name : Colin, Cécile (UNESCOG)
   Profile : Senior scientist
   Skills : Electrophysiological studies on speech perception and audio-visual integration

9. Name : Leproult, Rachelle (UR2NF)
   Profile : Post-doctoral

Skills : Sleep EEG, MEG, sleep and cognition

10. Name : Gaillard, Vinciane (CO3)
 Profile : Post-doctoral
 Skills : Working memory, implicit learning, life-long learning

11. Name : Chetail, Fabienne (LCLD)
 Profile : Post-doctoral
 Skills : Visual word recognition, orthographic coding, phonological and orthographic statistics

12. Name : Dubois, Matthieu (LCLD)
 Profile : Post-doctoral
 Skills : Visual perception and attention, letter and word perception

13. Name : Collet, Grégory (UNESCOG)
 Profile : PhD student
 Skills : Plasticity in speech perception : effects of explicit training

14. Name : Calcus, Axelle (UNESCOG)
 Profile : PhD student
 Skills : Speech perception and reading troubles : speech in noise perception in dyslexia and associated auditory brainstem responses

15. Name : Deliens, Gaétane (UR2NF)
 Profile : PhD student
 Skills : Sleep and memory, emotion, sleep EEG and sleep deprivation

16. Name : Schmitz, Rémy (UR2NF)
 Profile : PhD student
 Skills : Sleep and memory, sleep deprivation, laterality

17. Name : Urbain, Charline (UR2NF)
 Profile : PhD student
 Skills : Sleep and memory in children and epilepsy, neuroimaging (fMRI, MEG)

18. Name : Vermeiren, Astrid (CO3)
 Profile : PhD student
 Skills : Associative learning, subjective and objective measures, MEG

19. Name : Magalhaes, Pedro (CO3)
 Profile : PhD student
 Skills : Hypnosis, suggestion & placebo effects

20. Name : Windey, Bert (CO3)
 Profile : PhD student
 Skills : Visual perception, subliminal perception, psychophysics

21. Name : Atas, Anne (CO3)
 Profile : PhD student
 Skills : Subliminal perception, training effects in perception

22. Name : Bernacki, Angélique
 Profile : Secretary
 Skills : Administration

Form O: Publications

Give a list of the 5 to 10 recent and most relevant publications within the framework of the proposed research.

[Note : Considering the large size of the group (65 scientists), we have listed more than 10 references below]

Bayne, T., **Cleeremans, A.**, & Wilken, P. (2009). *The Oxford Companion to Consciousness*. Oxford: Oxford University Press.

Destrebecqz, A., & **Cleeremans, A.** (2001). Can sequence learning be implicit? New evidence with the Process Dissociation Procedure, *Psychonomic Bulletin & Review*, *8*(2), pp. 343-350.

Maquet, P., Laureys, S., Peigneux, P., Fuchs, S., Petiaux, C., Phillips, C., Aerts, J., Delfiore, G., Degueldre, C., Meulemans, T., Luxen, A., Franck, G., Van der Linden, M., Smith, C., & **Cleeremans, A.** (2000). Experience-dependent changes in cerebral activation during human REM sleep, *Nature Neuroscience, 3(8)*, 831-836.

Dehaene, S., Pegado, F., Braga, L. W., Ventura, P., Nunes, G. Jobert, A., Dehaene-Lambertz, G., **Kolinsky, R.** , Morais, & Cohen, L. (2010). How learning to read changes the cortical networks for vision and language ("Research article"). *Science, 33*0, 1359-1364. First published on line in Science Express, November 11. IF 31.364

Kolinsky, R., Verhaeghe, A., Fernandes, T., Mengarda, E. J., Grimm-Cabral, L., & Morais, J., (2011). Enantiomorphy through the Looking-Glass: Literacy effects on mirror-image discrimination. *Journal of Experimental Psychology: General, 140* (2), 210-238. Online First Publication, January 31, 2011. IF 5.042

Ventura, P., Morais, J. & **Kolinsky, R.**, (2007). The development of the orthographic consistency effect in speech recognition: from sublexical to lexical involvement. *Cognition, 105*, 547-576. IF 4.304

Content, A., Kearns, R., & Frauenfelder, U. (2001). Boundaries versus onsets in syllabic segmentation. *Journal of Memory and Language*, 45, 177-199.

Content, A., Meunier, C., Kearns, R. & Frauenfelder, U. (2001). Sequence detection in pseudowords in French: where is the syllable effect ? *Language and cognitive processes*, 16, 609-636

Peereman, R., & **Content, A.** (1997). Orthographic and phonological neighborhoods in naming: Not all neighbors are equally influential in orthographic space. *Journal of Memory and Language*, 37, 382-410.

Schmidt C, Collette F, Leclercq Y, Sterpenich V, Vandewalle G, Berthomier P, Berthomier C, Philipps C, Tinguely G, Darsaud A, Gais S, Schabus M, Desseilles M, DangVu TT, Salmon E, Balteau E, Degueldre C, Luxen A, Maquet P, Cajochen C, and **Peigneux P.**, (2009). Homeostatic sleep pressure and responses to sustained attention in the suprachiasmatic area. *Science* 324(5926),516-9. IF 30.631

Schmidt C, **Peigneux P**, Maquet P, and Philipps C., (2010). Response to Comment on "Homeostatic sleep pressure and responses to sustained attention in the suprachiasmatic area" *Science* 328(5976), 309

Gais S, Albouy G, Boly M, Dang-Vu TT, Darsaud A, Desseilles M, Rauchs G, Schabus M, Sterpenich V, Vandewalle G, Maquet, P and **Peigneux**, **P** (2007). Sleep transforms the cerebral trace of declarative memories *PNAS USA*, 104, 18778-83. IF 10,2310

Peigneux P, Orban P, Balteau E, Degueldre C, Luxen A, Laureys S, Maquet P (2006). Offline Persistence of Memory-Related Cerebral Activity during Active Wakefulness. *PLoS Biology*, 4, 647-658. IF 14,6720

FORM P: INTERNATIONAL CONTACTS IN THE PROPOSAL'S RESEARCH DOMAIN

Mention the most important international contacts and the international networks to which the partner belongs within the context of the proposal.

Consciousness, Cognition & Computation Group (CO3), Axel Cleeremans

- Luis Jiménez, Universidad de Santiago de Compostela, Spain
- Zoltan Dienes, University of Sussex, U.K.
- Anil Seth, University of Sussex, U.K.
- Morten Overgaard, University of Aarhus, Denmark
- Andreas Engel, University Medical Center Hamburg-Eppendorf, Germany
- Geraint Rees, University College London, U.K.
- Kai Vogeley, Uniklinik Köln, Germany
- Pierre Perruchet, Université de Bourgogne, France
- Andy Bremner, Goldsmith College, U.K.
- Robert M. French, Université de Bourgogne, France
- Denis Mareschal, Birkbeck College, U.K.
- Michal Wierzchon, Jagellonian University, Poland

Cognitive Neuroscience Unit (UNESCOG), Régine Kolinsky

- Dr. Stanislas Dehaene, Laboratoire de neuroimagerie cognitive, NEUROSPIN CEA, Saint-Aubin/Saclay, France

  Thematic Research : Cognitive and brain consequences of literacy.

  Collaborative elements in this intervention : Participation to some of the face perception studies; behavioural and brain-imaging studies on illiterate adults
- Dr. Tânia Fernandes, University of Porto,

  Thematic Research : Cognitive consequences of literacy

  Collaborative elements in this intervention : Participation to behavioural studies on illiterate adults
- Dr. Miguel Castelo-Branco, IBILI (Institute of Biomedical Research in Light and Image), Faculty of Medicine, University of Coimbra, Coimbra, Portugal

  Thematic Research : Cognitive and brain consequences of literacy.

  Collaborative elements in this intervention : Brain-imaging studies on illiterate adults
- Dr. Paulo Ventura, Faculty of Psychology, Universidade de Lisboa, Lisbon, Portugal

  Thematic Research : Cognitive consequences of literacy

  Collaborative elements in this intervention : Participation to some of the studies on illiterate adults
- Dr. Leonor Scliar-Cabral & Dr. Celina Macedo, Department of Linguistics and Literature in Vernacular Languages, Federal University of Santa Catarina (Universidade Federal de Santa Catarina, UFSC), Florianópolis, Brazil.

  Thematic Research : Cognitive consequences of literacy

  Collaborative elements in this intervention : Participation to some of the behavioural studies on illiterate adults
- Dr. Marcus Maia and Dr. Antonio Ribeiro, Laboratório de Psicolingüística Experimental (LAPEX), Dr. Aniela Improta**,** LAPEx & Programa Avançado de Neurociência, Federal University of Rio (Universidade Federal do Rio de Janeiro, UFRJ), Rio de Janeiro, Brazil.

  Thematic Research : Cognitive and brain consequences of literacy.

Collaborative elements in this intervention : Participation to some of the behavioural studies and to electrophysiological studies on illiterate adults.

- Dr. Beatrice de Gelder

  Cognitive and affective neuroscience laboratory, Tilburg University, Tilburg, The Netherlands

  Thematic Research : Cognitive and brain consequences of literacy.

  Collaborative elements in this intervention : Participation to some of the face perception studies

- Dr. Willy Serniclaes

  Université Paris Descartes, Laboratoire Psychologie de la Perception, Paris, France

  Thematic Research : Speech Perception, literacy and dyslexia

  Collaborative elements in this intervention : Participation to speech perception studies on dyslexic children

- Dr. Christian Lorenzi

  LPP – Hearing group, Département d'Etudes Cognitives, Ecole Normale Supérieure, CNRS, Université Paris- Descartes, Paris, France

  Thematic Research : Speech Perception

  Collaborative elements in this intervention : Participation to speech-in-noise perception studies on dyslexic children and illiterate adults.

Research Unit in Neuropsychology and Neuroimaging (UR2NF), Philippe Peigneux

- BENALI Habib, INSERM - CHU Pitié-Salpêtrière, U494 Imagerie Multimodalité quantitative du cerveau en action, Paris, France
- DOYON Julien, Université de Montréal, Functional Neuroimaging Unit & Department of Psychology, Montreal, Canada
- SCHABUS Manuel, University of Salzburg, Sleep Laboratory Division of Physiological Psychology, Salzburg, Autriche

FORM Q: CONTRACTS IN PROGRESS IN THE PROPOSAL'S RESEARCH DOMAIN

Give a list of research projects currently carried out in the field of the proposal with the duration and the funding source (Belgium's Federal Government, Communities and Regions or by the European Union).

Consciousness, Cognition & Computation Group (CO3), Axel Cleeremans

2006-2011 : Co-Principal Investigator/Coordinator, "Concerted Research Action" grant for a research project titled "Culturally Modified Organisms: What it means to be human in the age of culture (co-PIs: R. Kolinsky, O. Klein, A. Content, M. Dominicy, J.-N. Missa, J. Leybaert). €640.000

2007-2011 : Chair, COST ACTION BM0605
European COST ACTION dedicated to "Consciousness: A transdisciplinary, integrated approach".

2010-202 : MIS project F.4524.10 (Promotor : A. Destrebecqz) : Mécanismes élémentaires de l'apprentissage statistique implicite et de la cognition sociale : une approche développementale

Cognitive Neuroscience Unit (UNESCOG), Régine Kolinsky

All the project in the filed of the proposal (1 FRFC grant, 1 ARC grant, 1 Brains Back to Brussels grant) ended October 1, 2011

Cognition, Language and Development Laboratory (LCLD), Alain Content

2009-2012 : FNRS Research project CC-1.5.136.10.F/CTP-C.J.056.10.F : The role of syllabic structure in visual word recogntion. A. Content (PI), F. Chetail (postdoctoral researcher). €130.000

Research Unit in Neuropsychology and Neuroimaging (UR2NF), Philippe Peigneux

2009-2012 : FRSM project 3.4.582.09.F (principal promotor): Neural bases of learning and long term consolidation of sequential regularities. Combined effects of discrete vs. continuous learning mode and post-training sleep. Other promotors Dr P Maquet (ULg), Prof A Cleeremans (ULB), Prof P Van Boagert (ULB)

Combined by FNRS request with:

2009-2012 : FRFC project 2.4.627.09.F (co- promotor): The structuration of information in memory: A behavioural and imaging approach of the temporal course of learning. Other promotor Prof A Cleeremans (principal promotor, ULB)

FORM R: WORK PACKAGES IN WHICH THE PARTNER WILL BE PARTICIPATING

1. Work package number and title:
   WP1 Mechanisms and dynamics of learning and consolidation of novel visual patterns (faces). Lead Parner : P5 (UCL- Rossion). Associated teams : P1 (ULB-Cleeremans & Peigneux)

2. Work package number and title:
   WP2: Mechanisms of conditioning and causal learning. Lead Partner: P4 (KUL – Beckers). Associated teams: P2 (UG – De Houwer) & P1 (P1a: ULB – Cleeremans & Peigneux; P1b: Kolinsky).

3. Work package number and title:
   WP3: Mechanisms of learning via instructions. Lead Partner: P2 (UG – De Houwer). Associated teams: P1 (ULB – Cleeremans), P3 (UG – Brass) & P4 (KUL – Beckers).

4. Work package number and title:
   WP4: Mechanisms of implicit learning. Lead Partner: INT2 (Sussex – Dienes). Associated teams: P1 (ULB – Cleeremans) & P4 (KUL — Beckers).

5. Work package number and title:
   WP5: Mechanisms of human decision making. Lead Partner: P3 (UG – Brass). Associated teams: P1 (ULB – Cleeremans & Peigneux) & INT1 (UCL – Haggard).

6. Work package number and title:
   WP6: Mechanisms of instrumental learning and the conscious sense of agency. Lead partner: INT1 (UCLondon – Haggard). Associated teams: P1 (ULB – Cleeremans) & P3 (UG – Brass)

7. Work package number and title:
   WP7: Mechanisms of awareness: Learning to be conscious. Lead Partner: P1 (ULB – Cleeremans). Associated teams: P3 (UG – Brass), P5 (UCL – Rossion), INT1 (UCLondon – Haggard) & INT2 (Sussex – Dienes)

8. Work package number and title:
   WP8: Mechanisms of cultural learning: Neural recycling and neural competition. Lead Partner: P1 (ULB – Kolinsky & Content). Associated teams: P5 (UCL – Rossion) & P2 (UG – De Houwer)

9. Work package number and title:
   WP9: Project management. Lead Partner: P1 (ULB – Cleeremans)

FORM S: BUDGET (distribution per year) *

(in EURO without decimals)

	2012**	2013	2014	2015	2016	2017**	Total
Personnel	142 350	175 332	180 036	184 284	188 556	32 164	**902 722**
Operating costs	45 000	60 000	60 000	60 000	60 000	10 000	**295 000**
Equipment	16 000	16 000	16 000	16 000	Not allowed	Not allowed	**64 000**
Overheads	9 368	11 767	12 002	12 214	12 428	2 108	**59 886**
Subcontracting	0	0	0	0	0	0	**0**
Total	**212 718**	**263 099**	**268 038**	**272 498**	**260 984**	**44 272**	**1 321 608**

- Personnel: indexed gross remunerations, employer's social contributions and statutory insurance costs as well as any other compensation or allocation legally due in addition to the salary. This heading must account for 60% minimum of the total budget.

- Operating costs: basic supplies and products for laboratory, workshop or office; documentation, travel and accommodation; use of computing facilities; software; telecommunications; maintenance and operation of equipment and, more generally, consumables; hosting of visiting foreign researchers.

- Equipment: acquisition and installation of scientific and technical appliances and instruments, including IT equipment placed at the project's disposal.

- Overheads: general expenses of the institutions covering, on an inclusive basis, administrative, telephone, postal, maintenance, heating, lighting, electricity, rental, material depreciation and insurance costs (the total amount for this heading may not exceed 5% of total personnel and operating costs).

- Subcontracting: costs incurred by a third party in order to perform tasks or provide services necessitating specific scientific or technical skills outside the normal framework of the institution's activities (the amount may not exceed 25% of the total budget).

* Table not to be completed by the international partner

** from the first of March 2012 until the end of February 2017

BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 ▪ Fax +32 2 230 59 12
www.belspo.be

Interuniversity Attraction Poles (IAP)
Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION II

Information on the partners

To be filled in by each network partner
including the international partner

Attention: Before filling in this submission form, please read carefully the information document of the call

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words): **Mechanisms of conscious and unconscious learning**	
Proposal's acronym:	**COOL**
Name of the partner: **De Houwer, Jan** Institution: **Ghent University**	
Code (Reserved for BELSPO) :	

FORM L: PARTNER CONTACT DETAILS

PARTNER N° (consult the list in Section I - Form A)*: P2

- Family Name : De Houwer
- First Name : Jan
- Title (Prof., Dr., …) : Professor
- Institution : Ghent University
- Institution's abbreviation : UGent
- Faculty/Department : Department of Experimental Clinical and Health Psychology
- Research Unit : Learning and Implicit Processes Laboratory
- Road/Street, n° : Henri Dunantlaan 2
- Postal Code : 9000
- Town/City : Gent
- Country : Belgium
- Tel : 09 264 64 45
- Tel secretariat : 09 264 64 62
- Fax : 09 264 64 89
- E-mail : Jan.DeHouwer@UGent.be
- Website : http://www.implicit.ugent.be/liplab/

* For Belgian partners : P1 to P16
For International partners : INT1 to INT4

FORM M: STAFF MEMBERS OF THE PARTNER TEAM (by profile)

Indicate the number of currently working staff members in the research team of the partner

Profile	Number
Professor	2
Senior scientist	0
Post-doc	7
PhD student	8
Researcher without PhD	0
Technician	1
Secretary	0
Other	1
TOTAL	**19**

FORM N: STAFF MEMBERS WORKING ON THE PROJECT

Indicate the name, profile (professor, senior scientist, post-doctoral, PhD student, researcher without PhD, technician, secretary or other) and areas of skills (5 lines maximum) of the key persons currently working within the project's framework.

1. Name : De Houwer, Jan
   Profile : Professor
   Skills : The research of Prof. De Houwer concerns the manner in which automatic preferences are learned and can be measured. He focuses on the role of stimulus pairings and high-level processes. This research has led to theoretical, conceptual, and empirical contributions concerning evaluative and non-evaluative types of learning. With regard to the measurement of preferences, he developed new reaction time measures and examined the processes underlying various measures.

2. Name : Moors, Agnes
   Profile : Professor
   Skills : Prof. Moors will contribute to the project mainly at the theoretical and conceptual level. Her areas of expertise include (a) the conceptual analysis of automaticity and the relation between consciousness, attention, and control, (b) the conceptual analysis of appraisal variables, (c) the comparison of emotion theories (with regard to emotion causation and regulation), (d) dual process models, and (e) the usefulness of a levels of analysis approach for psychological theory building.

3. Name : Spruyt, Adriaan
   Profile : Post-doctoral researcher
   Skills : Dr. Spruyt focuses on the impact of personal goals and task-demands on lower-level automatic processes. This includes both processes involved in the activation of evaluative information and processes involved in the learning of preferences. He uses this theoretical knowledge to improve implicit measures of preferences.

4. Name : Liefooghe, Baptist
   Profile : Post-doctoral researcher
   Skills : Dr. Liefooghe conducts research on task-switching and (operant) learning via instruction. More specifically, he explores the impact of merely instructed tasks on performance during other related tasks.

5. Name : Gast, Anne
   Profile : Post-doctoral researcher
   Skills : Dr. Gast examines evaluative processing. Her research focuses mainly on evaluative conditioning (i.e., associative learning of preferences and in particular on whether and how evaluative conditioning can be explained by high-level (propositional) learning accounts. She is also interested in implicit measures (mainly affective priming and IAT), in regulatory effects on attention, and in philosophy of science.

6. Name : Schmidt, James
   Profile : Post-doctoral researcher
   Skills : The research of Dr. Schmidt primarily concerns the study of human contingency learning, that is, the study of how we learn what events and outcomes go together. In line with this work, he has been developing a computational model of episodic memory for simulating the results of performance (i.e., reaction time) tasks.

7. Name : Zanon, Riccardo
   Profile : PhD student
   Skills : Together with Jan De Houwer and Anne Gast, he examines the impact of high-level processes on evaluative conditioning (associative learning of preferences) and develops ways of capturing propositional aspects of automatic reactions.

Form O: Publications

Give a list of the 5 to 10 recent and most relevant publications within the framework of the proposed research.

Bar-Anan, Y., De Houwer, J., & Nosek, B. (2010). Evaluative conditioning and conscious knowledge of contingencies: A correlational investigation with large samples. Quarterly Journal of Experimental Psychology, 63, 2313-2335.

De Houwer, J. (2009). The propositional approach to associative learning as an alternative for association formation models. Learning & Behavior, 37, 1-20.

De Houwer, J., & Beckers, T. (2002). A review of recent developments in research and theory on human contingency learning. Quarterly Journal of Experimental Psychology, 55B, 289-310.

De Houwer, J., Beckers, T., & Vandorpe, S. (2005). Evidence for the role of higher-order reasoning processes in cue competition and other learning phenomena. Learning & Behavior, 33, 239-249.

De Houwer, J., Thomas, S., & Baeyens, F. (2001). Associative learning of likes and dislikes: A review of 25 years of research on human evaluative conditioning. Psychological Bulletin, 127, 853–869.

Gawronski, B., Rydell, R. J., Vervliet, B., & De Houwer, J. (2010). Generalization versus contextualization in automatic evaluation. Journal of Experimental Psychology: General, 139, 683-701.

Hofmann, W., De Houwer, J., Perugini, M., Baeyens, F., & Crombez, G. (2010). Evaluative conditioning in humans: A meta-analysis. Psychological Bulletin, 136, 390-421.

Mitchell, C. J., De Houwer, J., & Lovibond, P. F. (2009). The propositional nature of human associative learning. Behavioral and Brain Sciences, 32, 183-198.

Moors, A., & De Houwer, J. (2006). Automaticity: A conceptual and theoretical analysis. Psychological Bulletin, 132, 297-326.

Schmidt, J., R., De Houwer, J., & Besner, D. (2010). Contingency learning and unlearning in the blink of an eye: A resource dependent process. Consciousness & Cognition, 19, 235-250.

FORM P: INTERNATIONAL CONTACTS IN THE PROPOSAL'S RESEARCH DOMAIN

Mention the most important international contacts and the international networks to which the partner belongs within the context of the proposal.

Jan De Houwer heads the FWO Research Community (WOG) "Automatic processes in psychopathology and health related behaviour" (2006-2011). Funding for the current Research Community will end in December 2011 but an application has been submitted for a 5 year renewal. During this second period, the focus of the Research Community will shift to learning, that is, to ways of installing and changing automatic processes.

Collaborations with international partners that have led to joint publications related to the topic of the proposal:

- Yoav Bar-Anan and Brian Nosek (University of Virginia, USA)
- Dermot Barnes-Holmes (University of Maynooth, Ireland)
- Andy Field (Universty of Sussex, UK)
- Matt Field (University of Liverpool, UK)
- Bertram Gawronski (University of Western Ontario, Canada)
- Jorg Huijding (Erasmus Universiteit Rotterdam, Nederland)
- Wilhelm Hofmann (University of Chicago, USA)
- Helena Matute and Miguel Vadillo (Deusto University, Spain)
- Ralph Miller (SUNY Binghamton, USA)
- Chris Mitchell and Peter Lovibond (UNSW, Australia)

Member of the Experimental Psychology Society (EPS; UK), Psychonomic Society (USA).
Organizer of several international meetings and symposia on (evaluative) learning.

FORM Q: CONTRACTS IN PROGRESS IN THE PROPOSAL'S RESEARCH DOMAIN

Give a list of research projects currently carried out in the field of the proposal with the duration and the funding source (Belgium's Federal Government, Communities and Regions or by the European Union).

2010-2014 : FWO research project G076611N : Darwin's truth: Rule-based generalization and analogical reasoning in rats. Tom Beckers, Jan De Houwer, and Rudi D'hooghe. € 348.644

2008-2015 : Methusalem, Flemish Government - Ghent University : New directions in research on the acquisition and generation of attitudes. Jan De Houwer. € 3.681.500

2005-2011: GOA grant, Ghent University : Do automatic processes and cognitions have a causal impact on clinical and health related behavior? De Houwer, Jan, & Crombez, Geert. €1.400.000

FORM R: WORK PACKAGES IN WHICH THE PARTNER WILL BE PARTICIPATING

1. Work package number and title:
   WP2: Mechanisms of conditioning and causal learning. Lead Partner: P4 (KUL – Beckers). Associated teams: P2 (UG – De Houwer) & P1 (P1a: ULB – Cleeremans & Peigneux; P1b: Kolinsky).

2. Work package number and title:
   WP3: Mechanisms of learning via instructions. Lead Partner: P2 (UG – De Houwer). Associated teams: P1 (ULB – Cleeremans), P3 (UG – Brass) & P4 (KUL – Beckers).

3. Work package number and title:
   WP8: Mechanisms of cultural learning: Neural recycling and neural competition. Lead Partner: P1 (ULB – Kolinsky & Content). Associated teams: P5 (UCL – Rossion) & P2 (UG – De Houwer)

FORM S: BUDGET (distribution per year) *

(in EURO without decimals)

	2012**	2013	2014	2015	2016	2017**	Total
Personnel	17.779	114.484	119.574	122.993	143.012	0	**517.842**
Operating costs	2.000	10.000	10.000	10.000	10.000	10.000	**52.000**
Equipment	6.000	6.000		0	Not allowed	Not allowed	**12.000**
Overheads	989	6.224	6.479	6.650	7.651	500	**28.492**
Subcontracting	0	0	0	0	0	0	**0**
Total	**26.768**	**136.708**	**136.053**	**139.643**	**160.663**	**10.500**	**610.334**

- Personnel: indexed gross remunerations, employer's social contributions and statutory insurance costs as well as any other compensation or allocation legally due in addition to the salary. This heading must account for 60% minimum of the total budget.

- Operating costs: basic supplies and products for laboratory, workshop or office; documentation, travel and accommodation; use of computing facilities; software; telecommunications; maintenance and operation of equipment and, more generally, consumables; hosting of visiting foreign researchers.

- Equipment: acquisition and installation of scientific and technical appliances and instruments, including IT equipment placed at the project's disposal.

- Overheads: general expenses of the institutions covering, on an inclusive basis, administrative, telephone, postal, maintenance, heating, lighting, electricity, rental, material depreciation and insurance costs (the total amount for this heading may not exceed 5% of total personnel and operating costs).

- Subcontracting: costs incurred by a third party in order to perform tasks or provide services necessitating specific scientific or technical skills outside the normal framework of the institution's activities (the amount may not exceed 25% of the total budget).

* Table not to be completed by the international partner

** from the first of March 2012 until the end of February 2017

BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 ▪ Fax +32 2 230 59 12
www.belspo.be

Interuniversity Attraction Poles (IAP)
Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION II

Information on the partners

To be filled in by each network partner
including the international partner

Attention: Before filling in this submission form, please read carefully the information document of the call

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words): **Mechanisms of conscious and unconscious learning**
Proposal's acronym: **COOL**
Name of the partner: **Brass, Marcel** Institution: **Ghent University**

Code (Reserved for BELSPO) :

FORM L: PARTNER CONTACT DETAILS

PARTNER N° (consult the list in Section I - Form A)*: P3

- Family Name : Brass
- First Name : Marcel
- Title (Prof., Dr., …) : Professor Dr.
- Institution : Ghent University
- Institution's abbreviation : Ugent
- Faculty/Department :Faculty of Psychology and Educational Sciences, Department of Experimental Psychology
- Research Unit : Cognitive and motor control
- Road/Street, n° : Henri Dunantlaan 2
- Postal Code : 9000
- Town/City : Ghent
- Country : Belgium
- Tel : 003292646401
- Tel secretariat : 003292646494
- Fax : 003292646496
- E-mail : marcel.brass@ugent.be
- Website : http://users.ugent.be/~mbrass

* For Belgian partners : P1 to P16
For International partners : INT1 to INT4

FORM M: STAFF MEMBERS OF THE PARTNER TEAM (by profile)

Indicate the number of currently working staff members in the research team of the partner

Profile	**Number**
Professor	1
Senior scientist	
Post-doc	4
PhD student	6
Researcher without PhD	
Technician	
Secretary	
Other	
TOTAL	**11**

FORM N: STAFF MEMBERS WORKING ON THE PROJECT

Indicate the name, profile (professor, senior scientist, post-doctoral, PhD student, researcher without PhD, technician, secretary or other) and areas of skills (5 lines maximum) of the key persons currently working within the project's framework.

1. Name : Prof. Dr. Brass
   Profile : Professor (BOF, ZAP)
   Skills : Dr. Brass is heading the group motor and cognitive control. He has extensive experience in the domain of brain imaging and prefrontal cortex functioning. He is doing research on cognitive control, motor control, intentional action and the unconscious processes.

2. Name : Dr. Wouter De Baene
   Profile : Postdoctoral Researcher (FWO)
   Skills : Dr. De Baene has extensive experience in designing and analyzing fMRI experiments. He has used different fMRI analysis techniques such as parametric analysis and multivariate pattern analysis. Furthermore, he has experience with EEG and intracranial recordings. On the content level he is doing research on cognitive control.

3. Name : Dr. Simone Kühn
   Profile : Postdoctoral Researcher (FWO)
   Skills : Dr. Kühn is an expert in MRI analysis both on the structural and on the functional level. She has used multivariate pattern analysis and voxel based morphometry. Her research interest is in the domain of intentional action and non-action.

4. Name : Dr. Jelle Demanet
   Profile : Postdoctoral Researcher (Department)
   Skills : Dr. Demanet has extensive experience with behavioural research on cognitive control. More recently he started to acquire expertise in the domain of fMRI. His recent research is related to the interaction of top-down and bottom up influences on intentional behaviour. Furthermore, he is doing research on unconscious influences on human decisions.

5. Name : Dr. Michael Andres
   Profile : Postdoc (BOF, GOA)
   Skills : Dr. Andres is an expert in TMS research on motor control and number processing. Recently he started to do research on cognitive control.

6. Name : Egbert Hartstra
   Profile : PhD student (BOF)
   Skills : Mr. Harstra is currently finishing his PhD on the neural bases of implementing verbal instructions. He has carried out a series of brain imaging studies. Furthermore, he has experience with current methods to investigate functional connectivity such as DCM.

7. Name : Maggie Lynn
   Profile : PhD student (ECRP/FWO)
   Skills : Mrs. Lynn is working on an ERCP project on intentional inhibition of action. She has acquired some experience with high-level belief manipulations and the influence on intentional action. Furthermore, she has done research on sense of agency.

Form O: Publications

Give a list of the 5 to 10 recent and most relevant publications within the framework of the proposed research.

Hartstra, E., Kuhn, S., Verguts, T. & Brass, M. (2011). The implementation of verbal instructions: an fMRI study. *Human Brain Mapping*. (published online)

Rigoni, D., Kuehn, S., Satori, G. & Brass, M. (2011). Inducing disbelief in free will alters brain correlates of preconscious motor preparation. *Psychological Science, 22* (5), 613-618.

Krieghoff, V., Waszak, F., Prinz, W. & Brass, M. (2011). Neural and behavioural correlates of intentional actions. *Neuropsychologia.* 49(5), 767-776.

Brass, M. & Haggard, P. (2010). The hidden side of intentional action: the role of the anterior insular cortex. *Brain Structure and Function. 214* (5), 603-610.

Kuehn, S, Haggard, P. & Brass, M. (2009). Intentional inhibition. How the veto-area exerts control? *Human Brain Mapping, 30* (9)*, 2834-43.*

Brass, M., Wenke, D., Spengler, S. & Waszak, F. (2009). Neural correlates of overcoming interference from instructed and implemented stimulus-response associations. *Journal of Neuroscience 29 (6),* 1766-1772.

Soon, C.S., Brass, M., Heinze, H.-J. & Haynes, J.D. (2008). Unconscious determinants of free decisions in the human brain. *Nature Neuroscience, 11 (5),* 543-545.

Brass, M. & Haggard, P. (2008). The What, When, Whether model of intentional action. *The Neurocientist, 14,* 319-325.

Waszak, F., Wenke, D., & Brass, M. (2008). Cross-talk of instructed and applied arbitrary visuomotor mappings. *Acta Psychologica (Amst), 127 (1)*, 30-35.

Brass, M. & Haggard, P. (2007). To do or not to do: The neural signature of self control. *Journal of Neuroscience, 27*(34), 9141-9145.

FORM P: INTERNATIONAL CONTACTS IN THE PROPOSAL'S RESEARCH DOMAIN

Mention the most important international contacts and the international networks to which the partner belongs within the context of the proposal.

- Prof. Dr. Patrick Haggard, Institute of Cognitive Neuroscience, University College London, UK.
- Prof. Richard Ridderinkhof, University of Amsterdam, The Netherlands.
- Prof. Ap Dijksterhuis, Behavioural Science Institute, Radboud Unviersity, Nijmegen, The Netherlands.
- Prof. John-Dylan Haynes, Bernstein Centre for Computational Neuroscience, Charite Berlin, Germany.
- Dr. Florian Waszak, Universite Paris Descartes, France.
- Dr. Dorit Wenke, Humbodt University, Berlin, Germany.

Dr. Brass is part of a Collaborative Research Project of the European Research Foundation with partners from the UK (Prof. Patrick Haggard), Germany (Prof. Alexander Münchau) and Leiden (Prof. Eveline Crone).

FORM Q: CONTRACTS IN PROGRESS IN THE PROPOSAL'S RESEARCH DOMAIN

Give a list of research projects currently carried out in the field of the proposal with the duration and the funding source (Belgium's Federal Government, Communities and Regions or by the European Union).

2010-2014 : Intentional inhibition of human action. Collaborative Research Project V. European Science Foundation funded by FWO. Together with Patrick Haggard (UCL, London), Eveline Crone (Leiden University) and Alexander Münchau (University Hospital, Hamburg).

2008-2014 : Beyond localization: Neural networks of knowledge and cognitive control in the human brain. GOA of the Special Research Fund of Ghent University. Together with Wim Fias (University Ghent) and Tom Verguts (Ghent University).

2010-2015 : The integrative neuroscience of behavioural control. Together with nine other researchers from Ghent University. Multidisciplinary Research Partnership. (Ghent University).

FORM R: WORK PACKAGES IN WHICH THE PARTNER WILL BE PARTICIPATING

1. Work package number and title:
   WP3: Mechanisms of learning via instructions. Lead Partner: P2 (UG – De Houwer). Associated teams: P1 (ULB – Cleeremans), P3 (UG – Brass) & P4 (KUL – Beckers).

2. Work package number and title:
   WP5: Mechanisms of human decision making. Lead Partner: P3 (UG – Brass). Associated teams: P1 (ULB – Cleeremans & Peigneux) & INT1 (UCL – Haggard).

3. Work package number and title:
   WP6: Mechanisms of instrumental learning and the conscious sense of agency. Lead partner: INT1 (UCLondon – Haggard). Associated teams: P1 (ULB – Cleeremans) & P3 (UG – Brass)

4. Work package number and title:
   WP7: Mechanisms of awareness: Learning to be conscious. Lead Partner: P1 (ULB – Cleeremans). Associated teams: P3 (UG – Brass), P5 (UCL – Rossion), INT1 (UCLondon – Haggard) & INT2 (Sussex – Dienes)

FORM S: BUDGET (distribution per year) *
(in EURO without decimals)

	2012**	2013	2014	2015	2016	2017**	Total
Personnel	63.000,00 €	117.500,00 €	121.500,00 €	125.500,00 €	56.000,00 €	0	**483.500**
Operating costs	6.000	10.000	10.000	10.000	10.000	4.000	**50.000**
Equipment	20.000	4.000	4.000	0	Not allowed	Not allowed	**28.000**
Overheads	3.450	6.375	6.575	6.775	3.300	200	**26.675**
Subcontracting	0	0	0	0	0	0	**0**
Total	**92.450**	**137.875**	**142.075**	**142.275**	**69.300**	**4.200**	**588.175**

- Personnel: indexed gross remunerations, employer's social contributions and statutory insurance costs as well as any other compensation or allocation legally due in addition to the salary. This heading must account for 60% minimum of the total budget.

- Operating costs: basic supplies and products for laboratory, workshop or office; documentation, travel and accommodation; use of computing facilities; software; telecommunications; maintenance and operation of equipment and, more generally, consumables; hosting of visiting foreign researchers.

- Equipment: acquisition and installation of scientific and technical appliances and instruments, including IT equipment placed at the project's disposal.

- Overheads: general expenses of the institutions covering, on an inclusive basis, administrative, telephone, postal, maintenance, heating, lighting, electricity, rental, material depreciation and insurance costs (the total amount for this heading may not exceed 5% of total personnel and operating costs).

- Subcontracting: costs incurred by a third party in order to perform tasks or provide services necessitating specific scientific or technical skills outside the normal framework of the institution's activities (the amount may not exceed 25% of the total budget).

* Table not to be completed by the international partner

** from the first of March 2012 until the end of February 2017

BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 ▪ Fax +32 2 230 59 12
www.belspo.be

Interuniversity Attraction Poles (IAP)
Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION II

Information on the partners

To be filled in by each network partner
including the international partner

Attention: Before filling in this submission form, please read carefully the information document of the call

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words): **Mechanisms of conscious and unconscious learning**	
Proposal's acronym:	**COOL**
Name of the partner: **Beckers, Tom** Institution: **Katholieke Universiteit Leuven**	

Code (Reserved for BELSPO) :

FORM L: PARTNER CONTACT DETAILS

PARTNER N° (consult the list in Section I - Form A)*: P4

- Family Name : Beckers
- First Name : Tom
- Title (Prof., Dr., …) : Professor
- Institution : Katholieke Universiteit Leuven
- Institution's abbreviation : K.U.Leuven
- Faculty/Department :Psychology and Educational Sciences
- Research Unit : Psychology of Learning and Experimental Psychopathology
- Road/Street, n° : Tiensestraat 102
- Postal Code : 3000
- Town/City : Leuven
- Country : Belgium
- Tel : 016 32 61 34
- Tel secretariat : 016 32 60 01
- Fax : 016 32 60 99
- E-mail : tom.beckers@ppw.kuleuven.be
- Website : http://ppw.kuleuven.be/engish/clep/People/tb

* For Belgian partners : P1 to P16
For International partners : INT1 to INT4

FORM M: STAFF MEMBERS OF THE PARTNER TEAM (by profile)

Indicate the number of currently working staff members in the research team of the partner

Profile	Number
Professor	2
Senior scientist	1
Post-doc	1
PhD student	5
Researcher without PhD	
Technician	1
Secretary	1
Other	
TOTAL	**11**

FORM N: STAFF MEMBERS WORKING ON THE PROJECT

Indicate the name, profile (professor, senior scientist, post-doctoral, PhD student, researcher without PhD, technician, secretary or other) and areas of skills (5 lines maximum) of the key persons currently working within the project's framework.

1. Name : Tom Beckers
   Profile : Professor
   Skills : Fundamental processes of learning and conditioning in infant and adult humans and in rodents, using behavioural, neurobiological, and computational techniques. Cue competition in causal learning and conditioning. The role of learning and conditioning in psychopathology (particularly fear and addiction). Stimulus-response compatibility tasks. Approach-avoidance tendencies in psychopathology. Fear memory reconsolidation

2. Name : Frank Baeyens
   Profile : Professor
   Skills : Occasion setting and modulation, acquired equivalence and transfer of function across equivalence classes, cue competition, evaluative conditioning, flavor preference, observational learning, implicit learning, affective stimulus processing, contribution of psychology of learning to behavior therapy and health psychology

3. Name : Bram Vervliet
   Profile : Senior scientist
   Skills : Fear, anxiety, conditioning, human associative learning, perceptual and non-perceptual generalization, reconsolidation of human memory, psychophysiology, affective neuroscience, psychopharmacology

4. Name : Bridget McConnell
   Profile : Post-doc
   Skills : Associative learning and fear conditioning in humans and animals, extinction and recovery from extinction, memory retrieval

5. Name : Yannick Boddez
   Profile : PhD student
   Skills : Causal learning and contingency learning in humans, individual differences in complex fear learning, stimulus interaction effects, extinction, the relation between stimulus interaction effects and extinction, contextual modulation of the aforementioned phenomena, psychophysiology, generalization, animal learning

6. Name : Elisa Maes
   Profile : PhD student
   Skills : Analogical reasoning and rule-based generalization, behaviour genetics, behavioural phenotyping in rodents, animal cognition, conditioning

7. Name : Mathijs Franssen
   Profile : PhD student
   Skills : Conditioning, occasion setting, exemplar learning, categorization, belongingness, computational models of learning and cognition

8. Name : Bart Schepers
   Profile : PhD student
   Skills : Equivalence classes, learning mechanisms, amnesia, Korsakov, clinical neuropsychology, behaviour therapy

9. Name : Ellen Vervoort
   Profile : PhD student
   Skills : Non-perceptual generalization of conditioned fear, derived and functional equivalence, Pavlovian conditioning in humans

10. Name : Jeroen Clarysse
    Profile : Technician
    Skills : Software for control of human psychophysiological and behavioural experimentation, data acquisition procedures, hardware support

11. Name : An Van Kets
    Profile : Secretary
    Skills : Administration, logistics, organization

Form O: Publications

Give a list of the 5 to 10 recent and most relevant publications within the framework of the proposed research.

Beckers, T., De Houwer, J., & Matute, H. (Eds.) (2007). Human contingency learning [Special Issue]. *The Quarterly Journal of Experimental Psychology, 60*(3).

Beckers, T., Miller, R. R., De Houwer, J., & Urushihara, K. (2006). Reasoning rats: Forward blocking in Pavlovian animal conditioning is sensitive to constraints of causal inference. *Journal of Experimental Psychology: General, 135,* 92-102.

Beckers, T., & Vervliet, B. (2009). The truth and value of theories of associative learning. *Behavioral and Brain Sciences, 32,* 200-201.

Beckers, T., Vandorpe, S., Debeys, I., & De Houwer, J. (2009). Three-year-olds' retrospective revaluation in the blicket detector task: Backward blocking or recovery from overshadowing? *Experimental Psychology, 56,* 27-32.

Boddez, Y., Baeyens, F., Hermans, D., & Beckers, T. (2011). The hide-and-seek of retrospective revaluation: Recovery from blocking is context dependent in human causal learning. *Journal of Experimental Psychology: Animal Behavior Processes, 37,* 230-240.

Callaerts-Vegh, Z., Beckers, T., Ball, S. M., Baeyens, F., Callaerts, P. F., Cryan, J. F., Molnar, E., & D'Hooge, R. (2006). Concomitant deficits in working memory and fear extinction are functionally dissociated from reduced anxiety in metabotropic glutamate receptor 7-deficient mice. *The Journal of Neuroscience, 26,* 6573-6582.

Franssen, M., Clarysse, J., Beckers, T., van Vooren, P. R., & Baeyens, F. (2010). A free software package for a human online-conditioned suppression preparation. *Behavior Research Methods, 42,* 311-317.

Kindt, M., Soeter, M., & Vervliet, B. (2009). Beyond extinction: Erasing human fear responses and preventing the return of fear. *Nature Neuroscience, 12,* 256-258.

Van Gucht, D., Baeyens, F., Vansteenwegen, D., Hermans, D., & Beckers, T. (2010). Counterconditioning reduces cue-induced craving and actual cue-elicited consumption. *Emotion, 10,* 688-95.

FORM P: INTERNATIONAL CONTACTS IN THE PROPOSAL'S RESEARCH DOMAIN

Mention the most important international contacts and the international networks to which the partner belongs within the context of the proposal.

- Tom Beckers has an ongoing collaboration on developmental aspects of causal learning with the group of Prof. Teresa McCormack at Queen's University, Belfast, UK. This collaboration is currently funded by an ESRC research grant (see form Q)

- Intense contacts exist with the group of Prof. Merel Kindt at the University of Amsterdam, the Netherlands, on the role of conditioning processes in fear and anxiety. Tom Beckers is supervisor of two PhD students and a postdoc at UvA, and co-supervisor of two more PhD students. This collaboration is mainly funded through an NWO Vidi grant awarded to Tom Beckers (see form Q).

- Since working as a visiting assistant professor in the lab of prof. Ralph Miller (State University of New York at Binghamton, USA) in 2003-2004, an enduring collaboration was established concerning the role of inferential processes in animal conditioning. This has resulted in a number of joint publications and exchange of students. Most recently, a former PhD student from the Miller lab was awarded an FWO postdoctoral fellowship to work with Tom Beckers at K.U.Leuven.

- More recently, Tom Beckers spent 6 months to work with prof. Aaron Blaisdell as a visiting scholar at the University of California, Los Angeles (USA). The topic of collaboration was causal reasoning processes in rats. Collaborations to work on Bayesian modelling of flexible causal learning with prof. Alan Yuille and prof. Hongjing Lu started here as well.

- Within the European associative learning and fear conditioning communities, strong links exist with various groups, most particularly the groups of dr Raffael Kalisch at Hamburg University (Germany) and prof. Harald Lachnit at Marburg University (Germany) (see joint publications with Bram Vervliet from the K.U.Leuven team) as well as the group of prof. Helena Matute at Deusto University (Bilbao, Spain) (see co-edited special issue, joint publications, exchange of students and postdocs). Close contacts with other groups are maintained through yearly meetings of a European Human Fear Conditioning Network that was established by the K.U.Leuven group and includes all the major research groups in this domain in Europe, and through regular attendance at specialized meetings such as the yearly Associative Learning Symposium at Gregynog (UK), the yearly meeting of the Spanish Society for Comparative Psychology, and the 5-yearly meeting of the Australian Learning Group.

- Our group is also part of an FWO-funded Research Community that is coordinated by the group of prof. Jan De Houwer at Ghent University, concerning the role of automatic processes in psychopathology and health-related behaviour.

- Tom Beckers is a member of the Pavlovian Society, the prime scientific society devoted to the study of learning and memory phenomena and conditioning processes in humans and non-human animals. He was an invited speaker at their 2010 annual meeting.

FORM Q: CONTRACTS IN PROGRESS IN THE PROPOSAL'S RESEARCH DOMAIN

Give a list of research projects currently carried out in the field of the proposal with the duration and the funding source (Belgium's Federal Government, Communities and Regions or by the European Union).

2009-2011 : Economic and Social Research Council (UK): Research grant, *Reasoning and cue competition effects in causal learning: A developmental study* (co-promotor; £ 200.000; principal investigator: Teresa McCormack, Queen's University, Belfast)

2010-2015 : Netherlands Organisation for Scientific Research (NWO): Innovational Research Incentives Scheme Vidi grant, *Where has the fear gone - Is it lost, or has it just changed places?* (principal investigator; € 800.000)

2010-2017 : K.U.Leuven Research Council (BOF): Program Funding (PF), *GRIP*TT - Generalization Research in Ill health and Psychopathology: Transdiagnostic processes and Transfer of knowledge* (co-promotor; € 3.150.000; principal investigator: Dirk Hermans, K.U.Leuven)

2011-2015 : Research Foundation – Flanders (FWO – Vlaanderen): Research grant, *Affirming Darwin: Rule-based generalization and analogical reasoning in rats* (principal investigator; € 350.000)

FORM R: WORK PACKAGES IN WHICH THE PARTNER WILL BE PARTICIPATING

1. Work package number and title:
   WP2: Mechanisms of conditioning and causal learning. Lead Partner: P4 (KUL – Beckers). Associated teams: P2 (UG – De Houwer) & P1 (P1a: ULB – Cleeremans & Peigneux; P1b: Kolinsky).

2. Work package number and title:
   WP3: Mechanisms of learning via instructions. Lead Partner: P2 (UG – De Houwer). Associated teams: P1 (ULB – Cleeremans), P3 (UG – Brass) & P4 (KUL – Beckers).

3. Work package number and title:
   WP4: Mechanisms of implicit learning. Lead Partner: INT2 (Sussex – Dienes). Associated teams: P1 (ULB – Cleeremans) & P4 (KUL — Beckers).

FORM S: BUDGET (distribution per year) *

(in EURO without decimals)

	2012**	2013	2014	2015	2016	2017**	Total
Personnel	49,500	107,500	107,500	66,500	28,500	2,500	**362,000**
Operating costs	24,000	12,000	12,000	12,000	12,000	4,000	**76,000**
Equipment	25,000	5,000	5,000	5,000	Not allowed	Not allowed	**40,000**
Overheads	3,675	5,975	5,975	3,925	2,025	325	**21,900**
Subcontracting	0	0	0	0	0	0	**0**
Total	**102,175**	**130,475**	**130,475**	**87,425**	**42,525**	**6,825**	**499,900**

- Personnel: indexed gross remunerations, employer's social contributions and statutory insurance costs as well as any other compensation or allocation legally due in addition to the salary. This heading must account for 60% minimum of the total budget.

- Operating costs: basic supplies and products for laboratory, workshop or office; documentation, travel and accommodation; use of computing facilities; software; telecommunications; maintenance and operation of equipment and, more generally, consumables; hosting of visiting foreign researchers.

- Equipment: acquisition and installation of scientific and technical appliances and instruments, including IT equipment placed at the project's disposal.

- Overheads: general expenses of the institutions covering, on an inclusive basis, administrative, telephone, postal, maintenance, heating, lighting, electricity, rental, material depreciation and insurance costs (the total amount for this heading may not exceed 5% of total personnel and operating costs).

- Subcontracting: costs incurred by a third party in order to perform tasks or provide services necessitating specific scientific or technical skills outside the normal framework of the institution's activities (the amount may not exceed 25% of the total budget).

* Table not to be completed by the international partner

** from the first of March 2012 until the end of February 2017

BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 ▪ Fax +32 2 230 59 12
www.belspo.be

Interuniversity Attraction Poles (IAP)
Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION II

Information on the partners

To be filled in by each network partner
including the international partner

Attention: Before filling in this submission form, please read carefully the information document of the call

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words): **MECHANISMS OF CONSCIOUS AND UNCONSCIOUS LEARNING**
Proposal's acronym: **COOL**
Name of the partner: **Rossion, Bruno** Institution: **Université catholique de Louvain**

Code (Reserved for BELSPO) :

FORM L: PARTNER CONTACT DETAILS

PARTNER N° (consult the list in Section I - Form A)*: P5

- Family Name : ROSSION
- First Name : BRUNO
- Title (Prof., Dr., …) : Professor
- Institution : Université catholique de Louvain
- Institution's abbreviation : UCL
- Faculty/Department : Institute of research in Psychology and Institute of Neurosience
- Research Unit : Cognitive Neuroscience
- Road/Street, n° : Place de l'Université, 1
- Postal Code : 1348
- Town/City : Louvain-la-neuve
- Country : Belgium
- Tel : +32-10-478788
- Tel secretariat : +32-10-474096
- Fax : +32-10-473774
- E-mail : bruno.rossion@uclouvain.be
- Website : http://www.nefy.ucl.ac.be/Face_Categorisation_Lab.htm

* For Belgian partners : P1 to P16
For International partners : INT1 to INT4

FORM M: STAFF MEMBERS OF THE PARTNER TEAM (by profile)

Indicate the number of currently working staff members in the research team of the partner

Profile	Number
Professor	1
Senior scientist	--
Post-doc	4
PhD student	4
Researcher without PhD	--
Technician	--
Secretary	1 (10%)
Other	--
TOTAL	**10**

FORM N: STAFF MEMBERS WORKING ON THE PROJECT

Indicate the name, profile (professor, senior scientist, post-doctoral, PhD student, researcher without PhD, technician, secretary or other) and areas of skills (5 lines maximum) of the key persons currently working within the project's framework.

1. Name : Rossion, Bruno
   Profile : Professor
   Skills : My main research interest is to understand how does the human brain categorize objects of the visual world. I have a particular interest in the visual perception and recognition of a fascinating category of objects: faces.The face is undoubtedly a 'special' type of stimulus, with a long evolutionary history and a critical role in humans for social communication.To clarify the neuro-functional mechanisms of face perception, I strongly believe in the combination of data from various methods. We perform our own studies using neuroimaging (PET, fMRI), EEG and ERP, eye movement recordings, and behavioral studies in normal adults and children, as well as in brain-damaged people suffering from face recognition deficits (acquired prosopagnosia). This does not prevent us from having a rich network of international collaborators.

2. Name : Goedele Van Belle
   Profile : Post-doc
   Skills : Face perception, Eye-tracking methods, gaze-contingency, matlab coding

3. Name : Adélaïde de Heering
   Profile : Post-doc
   Skills : Face perception, Developmental studies

4. Name : Giulia Dormal
   Profile : PhD student
   Skills : Studies of blind patients, face perception, neuroimaging

5. Name : Renaud Laguesse
   Profile : PhD student
   Skills : Face perception, Behavioral methods

6. Name : Francesco Gentile
   Profile : Postdoc
   Skills : Face perception, Neuroimaging

Form O: Publications

Give a list of the 5 to 10 recent and most relevant publications within the framework of the proposed research.

Rossion, B., Schiltz, C., Robaye, L., Pirenne, D., Crommelinck, M. (2001) How does the brain discriminate familiar and unfamiliar faces: a PET study of face categorical perception. *Journal of Cognitive Neuroscience*, 13, 1019-1034.

Rossion, B., Kung, C.C., Tarr, M.-J. (2004). Visual expertise with nonface objects leads to competition with the early perceptual processing of faces in the human occipitotemporal cortex. *Proceedings of the National Academy of Science USA*, 101, 14521-14526.

Goffaux, V. & Rossion, B. (2006). Faces are "spatial"- Holistic face perception is supported by low spatial frequencies. *Journal of Experimental Psychology: Human Perception and Performance*.32, 1023-1039.

Rossion, B., Collins, D., Goffaux, V., Curran, T. (2007). Long-term expertise with artificial objects increases visual competition with early face categorization processes. *Journal of Cognitive Neuroscience*, 19, 543-555.

de Heering, A., de Liedekerke, C., Deboni, M., Rossion, B. (2010). The role of experience during childhood in shaping the other-race face effect. *Developmental Science,* 13, 181-187.

Van Belle, G., de Graef, P., Verfaillie, K., Busigny, T., Rossion, B. (2010). Whole not hole: expert face recognition requires holistic perception. *Neuropsychologia,* 48, 2609-2620.

Caharel, S., Jacques, C., d'Arripe, O., Ramon, M., & Rossion, B. (2011). Early electrophysiological correlates of adaptation to personally familiar and unfamiliar faces across viewpoint changes. *Brain Research,* 1387, 85-98.

Ramon, M., Caharel, S., & Rossion, B. (2011). The speed of personally familiar face recognition. *Perception,* 40, 437-449.

Van Belle, G., Busigny, T., Lefèvre, P., Joubert, S., Felician, O., Gentile, F., Rossion, B. (2011). Impairment of holistic face perception following right occipito-temporal damage in prosopagnosia: converging evidence from gaze-contingency. *Neuropsychologia*, 49, 3145-3150.

Jiang, F., Dricot, L., Weber, J., Righi, G., Tarr, M.J., Goebel, R., Rossion, B. (2011). Face categorization in visual scenes may start in a higher order area of the right fusiform gyrus: evidence from dynamic visual stimulation in neuroimaging. *Journal of Neurophysiology. In press*

FORM P: INTERNATIONAL CONTACTS IN THE PROPOSAL'S RESEARCH DOMAIN

Mention the most important international contacts and the international networks to which the partner belongs within the context of the proposal.

- Pr. Michael .J. Tarr
  Center for the Neural Basis of Cognition
  Carnegie Mellon University
  Psychology 4400 Fifth Avenue, CMU
  Pittsburgh, PA 15213 (USA)
  Phone: (412) 268-4379 / 3157
  fax: (412) 268-5060
  Email: michaeltarr@cmu.edu

- Prof. Tim. Curran
  Department of Psychology
  University of Colorado at Boulder
  Campus Box 345
  Boulder, CO 80309-0345 (USA)
  Phone: 303.492.5040
  Fax: 303.492.2967
  Email: tcurran@psych.colorado.edu

- Pr. Rainer. Goebel
  Dept. of Neurocognition, Faculty of Psychology
  Maastricht University
  P.O.Box 616
  6200 MD Maastricht (The Netherlands)
  Phone: +31 43 38 84014
  Fax: +31 43 38 84125
  Email: R.Goebel@psychology.unimaas.nl

- Pr. Jim Tanaka
  Department of Psychology
  University of Victoria
  Cornett Building, Room A189 (Canada)
  Phone: 250-721-7541
  Email: jtanaka@uvic.ca

FORM Q: CONTRACTS IN PROGRESS IN THE PROPOSAL'S RESEARCH DOMAIN

Give a list of research projects currently carried out in the field of the proposal with the duration and the funding source (Belgium's Federal Government, Communities and Regions or by the European Union).

2011 : ERC starting grant: Understanding the mechanisms of face perception: new insights from steady-state evoked potentials.

2008-2011 : FNRS "Mandat d'impulsion scientifique". Clarifier la neuro-anatomie fonctionnelle de la reconnaissance des visages chez l'Homme à partir d'études de neuroimagerie et délectrophysiologie du cas unique en neuropsychologie.

2007-2012 : Collective ARC grant, Communauté Française de Belgique, "Perception and Action" (together with E. Olivier, M. Crommelinck, M. Missal, P. Lefèvre; UCL).

FORM R: WORK PACKAGES IN WHICH THE PARTNER WILL BE PARTICIPATING

1. Work package number and title:
   WP1: Mechanisms and dynamics of learning and consolidation of novel visual patterns (faces). Lead Partner: P5 (UCL - Rossion). Associated teams: P1 (ULB –Cleeremans & Peigneux).

2. Work package number and title:
   WP7: Mechanisms of awareness: Learning to be conscious. Lead Partner: P1 (ULB – Cleeremans). Associated teams: P3 (UG – Brass), P5 (UCL – Rossion), INT1 (UCLondon – Haggard) & INT2 (Sussex – Dienes)

3. Work package number and title:
   WP8: Mechanisms of cultural learning: Neural recycling and neural competition. Lead Partner: P1 (ULB – Kolinsky & Content). Associated teams: P5 (UCL – Rossion) & P2 (UG – De Houwer)

FORM S: BUDGET (distribution per year) *

(in EURO without decimals)

	2012**	2013	2014	2015	2016	2017**	Total
Personnel	70 000	70 000	70 000	76 000	77 000	10 000	**373 000**
Operating costs	5 000	8 000	8 000	8 000	8 000	0	**37 000**
Equipment	40 000	0	0	5 000	Not allowed	Not allowed	**45 000**
Overheads	3 750	3 900	3 900	4 200	4 250	500	**20 500**
Subcontracting	4 500	5 000	5 000	5 000	5 000	0	**24 500**
Total	**123 250**	**86 900**	**86 900**	**98 200**	**94 250**	**10 500**	**500 000**

- Personnel: indexed gross remunerations, employer's social contributions and statutory insurance costs as well as any other compensation or allocation legally due in addition to the salary. This heading must account for 60% minimum of the total budget.

- Operating costs: basic supplies and products for laboratory, workshop or office; documentation, travel and accommodation; use of computing facilities; software; telecommunications; maintenance and operation of equipment and, more generally, consumables; hosting of visiting foreign researchers.

- Equipment: acquisition and installation of scientific and technical appliances and instruments, including IT equipment placed at the project's disposal.

- Overheads: general expenses of the institutions covering, on an inclusive basis, administrative, telephone, postal, maintenance, heating, lighting, electricity, rental, material depreciation and insurance costs (the total amount for this heading may not exceed 5% of total personnel and operating costs).

- Subcontracting: costs incurred by a third party in order to perform tasks or provide services necessitating specific scientific or technical skills outside the normal framework of the institution's activities (the amount may not exceed 25% of the total budget).

* Table not to be completed by the international partner

** from the first of March 2012 until the end of February 2017

BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 ▪ Fax +32 2 230 59 12
www.belspo.be

Interuniversity Attraction Poles (IAP)
Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION II

Information on the partners

To be filled in by each network partner including the international partner

Attention: Before filling in this submission form, please read carefully the information document of the call

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words): **Mechanisms of conscious and unconscious learning**
Proposal's acronym: **COOL**
Name of the partner: **Patrick Haggard** Institution: **University College London**

Code (Reserved for BELSPO) :

FORM L: PARTNER CONTACT DETAILS

PARTNER N° (consult the list in Section I - Form A)*: **INT1**

- Family Name : Haggard
- First Name : Patrick
- Title (Prof., Dr., …) : Prof
- Institution : University College London
- Institution's abbreviation : UCLondon
- Faculty/Department :Faculty of Brain Sciences
- Research Unit : Institute of Cognitive Neuroscience
- Road/Street, n° : Queen Square, 17
- Postal Code : WC1N 3AR
- Town/City : London
- Country : United Kingdom
- Tel : +44 207 679 1153
- Tel secretariat : +44 207 679 1177
- Fax : +44 207 813 2835
- E-mail : p.haggard@ucl.ac.uk
- Website : www.icn.ucl.ac.uk

* For Belgian partners : P1 to P16
For International partners : INT1 to INT4

FORM M: STAFF MEMBERS OF THE PARTNER TEAM (by profile)

Indicate the number of currently working staff members in the research team of the partner

Profile	Number
Professor	1
Senior scientist	
Post-doc	7
PhD student	6
Researcher without PhD	
Technician	0.25
Secretary	0.25
Other	
TOTAL	**14.5**

FORM N: STAFF MEMBERS WORKING ON THE PROJECT

Indicate the name, profile (professor, senior scientist, post-doctoral, PhD student, researcher without PhD, technician, secretary or other) and areas of skills (5 lines maximum) of the key persons currently working within the project's framework.

1. Name : Patrick Haggard
   Profile : PI
   Skills : Cognitive Neuroscience

2. Name : Valerian Chambon
   Profile : Postdoc, Fyssen Foundation
   Skills : fMRI, metacognition

3. Name : Erman Misirlisoy
   Profile : PhD student, ESRC
   Skills : cognitive control

4. Name : Jim Parkinson
   Profile : Postdoc, ESRC
   Skills : cognitive psychology, psychophysics, EEG

5. Form O: Publications

Give a list of the 5 to 10 recent and most relevant publications within the framework of the proposed research.

1 Haggard P, Clark S & Kalogeras J. (2002) Voluntary action and Conscious Awareness. *Nature Neuroscience*, *5*, 382-385.

2 Haggard P. (2005). Conscious Intention and Motor Cognition. *Trends in Cognitive Science*, *9*, 290-295.

3 Brass M & Haggard P. (2007). To do or not to do : the neural signature of self-control. *Journal of Neuroscience, 22*, 9141-9145.

4 Engbert K, Wohlschlaeger A & Haggard P (2008). Who is causing what? The sense of agency is relational and efferent-triggered. *Cognition, 107*, 693-704.

5 Moore JW, Lagnado D, Deal DC & Haggard P (2009). Feelings of control: contingency determines experience of action. *Cognition*, *110,* 279-283.

6 Moore JW, Wegner DM & Haggard P (2009). Modulating the sense of agency with external cues. *Consciousness and Cognition*, *18,* 1056-1064.

7 Haggard P (2008). Human volition: towards a neuroscience of will. *Nature Reviews Neuroscience*, *9,* 934-946.

8 Wenke D, Fleming SM & Haggard P (2010). Subliminal priming of actions influences sense of control over effects of action. *Cognition, 115,* 26-38.

FORM P: INTERNATIONAL CONTACTS IN THE PROPOSAL'S RESEARCH DOMAIN

Mention the most important international contacts and the international networks to which the partner belongs within the context of the proposal.

1. European Science Foundation, European Collaborative Research Project on 'Intentional Inhibition' (Coordinator). Other members include Marcel Brass (U Gent), Leiden and Hamburg.
2. EU/ESF COST Action BM0605. Coordinator of Short-term scientific missions for training in consciousness research.
3. EU/FP Integrated Projects (VERE and BEAMING). Research on scientific foundations of virtual reality and virtual embodiment.
4. Joint PhD Programme in Cognitive Neuroscience, co-supervision and management participation with Bologna University.
5. Max Planck Society Doctoral School IMPRS Neurocomm. Committee member, summer school organiser.

FORM Q: CONTRACTS IN PROGRESS IN THE PROPOSAL'S RESEARCH DOMAIN

Give a list of research projects currently carried out in the field of the proposal with the duration and the funding source (Belgium's Federal Government, Communities and Regions or by the European Union).

1. Intentional Inhibition. Funded by ESRC UK, under the European Science Foundation ECRP programme.
2. Fyssen Foundation, Postdoctoral Fellowship for Dr Valerian Chambon (ends 12/2011)
3. EU FP7. Funding by IPs VERE and BEAMING

FORM R: WORK PACKAGES IN WHICH THE PARTNER WILL BE PARTICIPATING

1. Work package number and title: WP5, Mechanisms of human decision making
2. Work package number and title: WP6, Mechanisms of instrumental learning and the conscious sense of agency
3. Work package number and title: WP7, Mechanisms of awareness: Learning to be conscious

FORM S: BUDGET (distribution per year) *
(in EURO without decimals)

	2012**	2013	2014	2015	2016	2017**	Total
Personnel	0	0	0	0	0	0	**0**
Operating costs	0	0	0	0	0	0	**0**
Equipment	0	0	0	0	Not allowed	Not allowed	**0**
Overheads	0	0	0	0	0	0	**0**
Subcontracting	0	0	0	0	0	0	**0**
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**

- Personnel: indexed gross remunerations, employer's social contributions and statutory insurance costs as well as any other compensation or allocation legally due in addition to the salary. This heading must account for 60% minimum of the total budget.

- Operating costs: basic supplies and products for laboratory, workshop or office; documentation, travel and accommodation; use of computing facilities; software; telecommunications; maintenance and operation of equipment and, more generally, consumables; hosting of visiting foreign researchers.

- Equipment: acquisition and installation of scientific and technical appliances and instruments, including IT equipment placed at the project's disposal.

- Overheads: general expenses of the institutions covering, on an inclusive basis, administrative, telephone, postal, maintenance, heating, lighting, electricity, rental, material depreciation and insurance costs (the total amount for this heading may not exceed 5% of total personnel and operating costs).

- Subcontracting: costs incurred by a third party in order to perform tasks or provide services necessitating specific scientific or technical skills outside the normal framework of the institution's activities (the amount may not exceed 25% of the total budget).

* Table not to be completed by the international partner

** from the first of March 2012 until the end of February 2017

BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 ▪ Fax +32 2 230 59 12
www.belspo.be

belspo

Interuniversity Attraction Poles (IAP)
Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION II

Information on the partners

To be filled in by <u>each network partner</u>
including the international partner

Attention: Before filling in this submission form, please read carefully the information document of the call

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words): **Mechanisms of conscious and unconscious learning**	
Proposal's acronym:	**COOL**
Name of the partner: **Zoltan Dienes** Institution: **University of Sussex**	

Code (Reserved for BELSPO) :

.be

FORM L: PARTNER CONTACT DETAILS

PARTNER N° (consult the list in Section I - Form A)*: **INT2**

- Family Name : Dienes
- First Name : Zoltan
- Title (Prof., Dr., …) : Prof
- Institution : University of Sussex
- Institution's abbreviation : US
- Faculty/Department : School of Psychology
- Research Unit : Dienes Research Group
- Road/Street, n° : Pevensey Building
- Postal Code : BN1 9QH
- Town/City : Brighton
- Country : United Kingdom
- Tel : +44 1 273 877335
- Tel secretariat : +44 1 273 877335
- Fax : +44 1 273 678058
- E-mail : dienes@sussex.ac.uk
- Website : www.lifesci.sussex.ac.uk/home/Zoltan_Dienes/

* For Belgian partners : P1 to P16
For International partners : INT1 to INT4

FORM M: STAFF MEMBERS OF THE PARTNER TEAM (by profile)

Indicate the number of currently working staff members in the research team of the partner

Profile	Number
Professor	1
Senior scientist	-
Post-doc	1
PhD student	4
Researcher without PhD	-
Technician	-
Secretary	-
Other	
TOTAL	**6**

FORM N: STAFF MEMBERS WORKING ON THE PROJECT

Indicate the name, profile (professor, senior scientist, post-doctoral, PhD student, researcher without PhD, technician, secretary or other) and areas of skills (5 lines maximum) of the key persons currently working within the project's framework.

1. Name : Zoltan Dienes
   Profile : Prof.
   Skills : measurement of conscious status of knowledge, computational modeling

2. Form O: Publications

Give a list of the 5 to 10 recent and most relevant publications within the framework of the proposed research.

Chen, W., Guo, X., Tang, J., Zhu, L., Yang, Z., & Dienes, Z. (2011). Unconscious Structural Knowledge of Form-meaning Connections. Consciousness & Cognition,

Dienes, Z. (2011). Conscious versus unconscious learning of structure. In P. Rebuschat & J. Williams (Eds), Statistical Learning and Language Acquisition. Mouton de Gruyter Publishers.

Zhang, L., Ma, W., & Dienes, Z. (2011). Acquisition of conscious and unconscious knowledge of semantic prosody. Consciousness & Cognition, 20, 417-425.

Scott, R.A., Minati, L., Dienes, Z., Critchley, H. D., & Seth, A. K. (2011). Detecting conscious awareness from involuntary autonomic responses. Consciousness & Cognition, 20, 936-942.

Dienes, Z., & Seth, A. (2010). Gambling on the unconscious: A comparison of wagering and confidence ratings as measures of awareness in an artificial grammar task. Consciousness & Cognition, 19, 674-681.

Fu, Q., Dienes, Z., & Fu, X. (2010). Can unconscious knowledge allow control in sequence learning? Consciousness & Cognition, 19, 462-475.

Reed, N., McLeod, P., & Dienes, Z. (2010). Implicit knowledge and motor skill: What people who know how to catch don't know. Consciousness & Cognition, 19, 63-76.

Scott, R. B., & Dienes, Z. (2010). Knowledge applied to new domains: The unconscious succeeds where the conscious fails. Consciousness & Cognition, 19, 391-398.

Scott, R. B., & Dienes, Z. (2010). Prior familiarity with components enhances unconscious learning of relations. Consciousness & Cognition, 19, 413-418.

Scott, R. B., & Dienes, Z. (2010). Fluency does not express implicit knowledge of artificial grammars. Cognition, 114, 372-388.

FORM P: INTERNATIONAL CONTACTS IN THE PROPOSAL'S RESEARCH DOMAIN

Mention the most important international contacts and the international networks to which the partner belongs within the context of the proposal.

Active collaborations with the following personalities:

Elisabeth Norman University of Bergen

Mark Price University of Bergen

Eleni Ziori University of Ioanina

Baruch Eitam The Hebrew University Jerusalem

Fu Qiufang Insitute of Psychology, Chinese Academy of Sciences, Beijing

Fu Xiaolan Insitute of Psychology, Chinese Academy of Sciences, Beijing

Guo Xiuyan School of Psychology and Cognitive Science, East China Normal University

Yang Zhiliang School of Psychology and Cognitive Science, East China Normal University

Lei Zhu Department of Psychology Fudan University Shanghai

Sachiko Kiyokawa Department of Psychology Chubu University Nagoya

Daisuke Tanaka Departemnt of psychology Tottori University

Irving Kirsch Department of psychology Harvard University

FORM Q: CONTRACTS IN PROGRESS IN THE PROPOSAL'S RESEARCH DOMAIN

Give a list of research projects currently carried out in the field of the proposal with the duration and the funding source (Belgium's Federal Government, Communities and Regions or by the European Union).

Economic and Social Research Council grant to hire a post doc for three years on subliminal perception and implicit learning. One year left

FORM R: WORK PACKAGES IN WHICH THE PARTNER WILL BE PARTICIPATING

1. Work package number and title: WP4, Mechanisms of implicit learning
2. Work package number and title: WP7, Mechanisms of awareness: Learning to be conscious

FORM S: BUDGET (distribution per year) *
(in EURO without decimals)

	2012**	2013	2014	2015	2016	2017**	Total
Personnel	0	0	0	0	0	0	**0**
Operating costs	0	0	0	0	0	0	**0**
Equipment	0	0	0	0	Not allowed	Not allowed	**0**
Overheads	0	0	0	0	0	0	**0**
Subcontracting	0	0	0	0	0	0	**0**
Total	**0**	**0**	**0**	**0**	**0**	**0**	**0**

- Personnel: indexed gross remunerations, employer's social contributions and statutory insurance costs as well as any other compensation or allocation legally due in addition to the salary. This heading must account for 60% minimum of the total budget.

- Operating costs: basic supplies and products for laboratory, workshop or office; documentation, travel and accommodation; use of computing facilities; software; telecommunications; maintenance and operation of equipment and, more generally, consumables; hosting of visiting foreign researchers.

- Equipment: acquisition and installation of scientific and technical appliances and instruments, including IT equipment placed at the project's disposal.

- Overheads: general expenses of the institutions covering, on an inclusive basis, administrative, telephone, postal, maintenance, heating, lighting, electricity, rental, material depreciation and insurance costs (the total amount for this heading may not exceed 5% of total personnel and operating costs).

- Subcontracting: costs incurred by a third party in order to perform tasks or provide services necessitating specific scientific or technical skills outside the normal framework of the institution's activities (the amount may not exceed 25% of the total budget).

* Table not to be completed by the international partner

** from the first of March 2012 until the end of February 2017

BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 ▪ Fax +32 2 230 59 12
www.belspo.be

Interuniversity Attraction Poles (IAP)
Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION III

Proposal summary (English, Dutch, French)

To be filled in by the network coordinator

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words) : **Mechanisms of conscious and unconscious learning**	
Proposal's acronym :	**COOL**
Name of the coordinator:	**Axel CLEEREMANS**
Institution:	**Université Libre de Bruxelles**

Code (Reserved for BELSPO) :

PROPOSAL SUMMARY IN ENGLISH

Proposal Title:

Mechanisms of conscious and unconscious learning

Short Title:

Conscious & unconscious learning

Summary of the proposal:

The overarching goal of this project is to contribute to our understanding of the mechanisms of conscious and unconscious learning. Learning, that is, the ability to respond adaptively to changing circumstances is a fundamental ability for any organism. Thanks to recent advances in imaging methods, it has now become clear that the brain is a fundamentally plastic organ, the functional architecture of which is continuously modified through experience. From this perspective, one could thus argue that learning is a mandatory consequence of information processing: We learn all the time, whether we intend to or not. Learning takes many different forms. For instance, contrast learning the fact that Steve Jobs has just passed away with learning how to perform the complex movements involved in dancing the flamenco. Consider the differences between learning how to solve an arithmetic problem with learning a second language. Contrast a baby learning how to walk with an adult learning to play tennis, or a rat learning to avoid an electric shock with a human learning about the Hundred-years War.

In all such cases, one can see similarities, but also differences. All such cases involve changing the representational and behavioural repertoire of an agent, but each seems to appeal to fundamentally different processes. In particular, a long-standing distinction is that between associative theories and cognitive theories of learning. An important consequence of this diversity is that research on learning continues to be unproductively **segregated into distinct subfields** that entertain little communication with each other. For instance, research on implicit learning — the process whereby one learns without intending to do so and without awareness that one has learned, has so far made little contact with research on high-level, conscious learning such as involved in causal reasoning or in problem solving. Likewise, research dedicated to understand the basic mechanisms of learning in animals such as rodents remains almost completely disconnected from research dedicated to understanding basic mechanisms of learning in humans.

The domain as whole also remains **very controversial**. At least three such continuing controversies can be identified. The **first** concerns whether learning depends on associative mechanisms, on effortful, intentional, propositional-like reasoning processes or on a combination of both. Experimentally, recent, controversial evidence has indicated that even animals such as rats can exhibit inferential processing, thus questioning one of the fundamental tenets of associative theories. Conceptually, some theories in the domain assume that all learning is based on associative learning (e.g., connectionism), others assume that all learning is based on the manipulation of propositional symbol structures, and yet others assume that the two kinds of processes operate jointly or that they compete with each other. The second controversial issue is the role that awareness plays in learning, and in particular, the extent and limits of what can be learnt without awareness. The third controversial issue concerns the respective role of top-down and bottom-up learning mechanisms and the nature of their interactions (i.e., are phenomena such as conditioning penetrable to instructions?) Crucially, the poles of these different distinctions are often cast as correlated. Thus, we have one system that learns associations, automatically, in the absence of awareness, and that involves mostly bottom-up processes. The second system, by contrast, learns through hypothesis testing and inference, results in propositional representations that are available to consciousness, and involves top-down mechanisms.

Here, **we propose to fundamentally reconsider the distinction**. Instead of assuming that associative learning is always unconscious, automatic and bottom-up and that cognitive learning is always conscious, effortful and top-down, we propose instead that mechanisms of change operate continuously, at all levels of the cognitive hierarchy as well as over different times scales (i.e., over the time course of a single trial, over learning, and over development). From this perspective, the brain is continuously and unconsciously learning to anticipate the consequences of action or activity on itself, on the world, and on other people. There is

considerable evidence for such predictive mechanisms in the human brain. This idea, in fact, forms the core of the Bayesian perspective on information processing and is at the heart of Friston's free energy principle, according to which the brain continuously attempts to minimize "surprise" or conflict by anticipating its own future activity based on learned priors.

In this light, we will focus on exploring three central lines of research, as follows:

The **first issue** concerns the computational mechanisms and the neural correlates that subtend associative and cognitive learning, as well as their interactions. One set of questions concerns the extent and limits of each type of learning. Do associative learning mechanisms have sufficient power to account for *all* learning? Humans and animals share much of their neural organization, but also differ in many ways, most significantly perhaps through the fact that the former can leverage the expressive power of language to use and share symbolic structures through culture, so that they can, for instance, learn much more efficiently through instruction. Conversely, is there evidence for the involvement of symbolic, propositional-like representations in organisms that have typically been considered unable to carry out inferential processes? A second set of questions concerns the dynamics that underlie the transition between associative and cognitive learning (e.g., insight ; the role played by the sleep-wake cycle in consolidating memories ; the mechanisms of automatization in skill learning). There is a genuine puzzle involved in understanding how one can go from associative, subsymbolic learning to full-fledged cognitive learning.

The **second issue** concerns the relationships between awareness and learning. There continues to be considerable debate about the extent to which humans can learn without awareness, particularly in domains such as conditioning or implicit learning. Here, we will systematically probe the limits of what can be learned without awareness. The role that consciousness plays in learning, and, conversely, the role that learning plays in shaping the contents of consciousness, are thus fundamental, yet wholly unsolved issues. Are the mechanisms involved in conscious and unconscious learning subtended by the same or by distinct neural structures? What are the limits of learning without awareness? What is the influence of high-level, conscious processes on lower-level phenomena such as conditioning or habituation? How do we best characterize the differences and commonalities between human and animal learning?

A **third issue** concerns the respective influences of top-down vs. bottom-up processes and their interactions. Functions like executive control and attention are typically considered to involve "top-down" mechanisms associated with awareness, but there is now both evidence for the possibility of unconscious executive control as well as evidence for the fact that attention can dissociate from consciousness. Particular emphasis will be put on understanding (1) how high-level processes such as reasoning, instruction-following and awareness can modulate lower-level, associative learning, and (2) how low-level, unconscious learning can shape further conscious, intentional processing, such as involved in decision-making or in action.

These lines of research will be addressed over a series of eight interconnected work packages that are specifically aimed at leveraging the respective expertise of the partners. The network comprises experts on consciousness (**P1** ULB—Cleeremans), on sleep and memory (**P1** ULB—Peigneux), on language development (**P1** ULB—Content), on literacy (**P1** ULB—Kolinsky), on associative learning and evaluative conditioning (**P2** UG—De Houwer), on intentional action and cognitive control (**P3** UG—Brass), on animal learning (**P4** KUL—Beckers) and on vision and perception (**P5** UCL—Rossion).

Further, the network has solicited the expert collaboration of two foreign partners: Pr. Patrick Haggard (**INT1**, University College London) for his expertise on volition and action, and .Pr. Zoltan Dienes (**INT2,** University of Sussex) for his expertise on implicit learning and unconscious processes. The partners know each other very well, having often already collaborated with each other. They not only share a deep interest in the importance of learning and plasticity in their respective domains but also have complementary skills and areas of expertise that will be leveraged to their full effect in this project. All have already received the full support of their respective institutions.

COOL is structured in eight workpackages (WP), each placed under the responsibility of one of the partners. The proposed research is strongly driven by a coherent novel perspective on how one should conceive of the traditional dichotomies described above, and addresses the fundamental role that conscious and unconscious learning play in different domains (e.g., memory, face perception, perceptual learning, literacy, animal learning, conditioning, decision-making, habituation, implicit learning, subliminal perception, volition). This innovative vision will result in an important step forward in understanding the fundamental ability of humans and other organisms to adapt to an ever-changing environment.

SAMENVATTING VAN HET VOORSTEL IN HET NEDERLANDS

Titel van het voorstel (maximum 20 woorden):

Mechanismen van bewust en onbewust leren.

Korte titel van het voorstel (maximum 3 woorden):

Bewust en onbewust leren

Samenvatting van het voorstel:

De omvattende doelstelling van dit project bestaat erin een bijdrage te leveren aan het begrijpen van de mechanismen van bewust en onbewust leren. Leren, het vermogen om adaptief te reageren op veranderende omstandigheden, is een fundamenteel vermogen van elk levend organisme. Dankzij recente ontwikkelingen in methodes van neuronale beeldvorming is duidelijk geworden dat de hersenen een fundamenteel adaptief orgaan is waarvan de architectuur voortdurend aangepast wordt op basis van ervaring. Vanuit dit perspectief kan men beargumenteren dat leren een dwingend gevolg is van het verwerken van informatie: We leren voortdurend, ongeacht of we dit nu willen of niet. Leren kan verschillende vormen aannemen. Vergelijk, bijvoorbeeld, het leren van het feit dat Steve Jobs recent is overleden met het leren uitvoeren van complexe bewegingen die betrokken zijn in flamenco dansen. Neem de verschillen tussen het leren oplossen van een rekenkundig probleem en het leren van een tweede taal. Vergelijk de manier waarop een baby leert wandelen met hoe een volwassen persoon leert tennissen, of hoe een rat leert om een elektrische schok te vermijden met hoe mensen over de Honderdjarige Oorlog leren.

Tussen al die situaties kan men gelijkenissen maar ook verschillen zien. Elk van die situaties omhelst een verandering in het representationele en gedragsrepertorium van een organisme maar elke situatie lijkt te berusten op fundamenteel verschillende processen. Eén van de gevolgen van die diversiteit is dat onderzoek naar leren op een onproductieve manier opgedeeld wordt in verschillende deeldomeinen die weinig met mekaar interageren. Bijvoorbeeld, onderzoek naar impliciet leren – het proces waardoor geleerd kan worden zonder intentie om te leren en bewustzijn van het geleerde – heeft tot dusver weinig contact gemaakt met onderzoek naar hogere-orde, bewuste vormen van leren zoals deze betrokken in causaal redeneren en probleem oplossing. Op gelijkaardige wijze blijft onderzoek naar de fundamentele mechanismen van leren door dieren bijna volledig los staan van onderzoek naar de fundamentele mechanismen van leren bij mensen.

Het domein van leerpsychologisch onderzoek blijft zeer controversieel. Minstens **drie controverses** kunnen geïdentificeerd worden. De eerste controverse betreft de vraag of leren gebaseerd is op associatieve mechanismen, op intentionele, propositionele redeneerprocessen, of op een combinatie van beide. Met betrekking tot de experimentele bevindingen, doen recente controversiële studies vermoeden dat zelfs dieren zoals ratten in staat zijn tot flexibele redeneren, waardoor deze studies een fundamentele assumptie van associatieve processen in vraag stellen. Op conceptueel vlak veronderstellen sommige theorieën dat alle leren gebaseerd is op associatieve processen (vb., connectionisme) terwijl andere theorieën postuleren dat alle leren gebaseerd is op een manipulatie van propositionele symbolische representaties, en nog andere onderzoekers veronderstellen dat deze twee types van processen samen werken of mekaar bevechten. Het tweede controversiële thema betreft de rol die bewustzijn speelt in leren en meer in het bijzonder de mate waarin leren kan optreden zonder bewustzijn van het geleerde. Het derde controversiële thema gaat over de interactie tussen top-down en bottom-up leerprocessen (vb., de wijze waarop fenomenen zoals conditionering beïnvloedbaar zijn door instructies). Wat cruciaal is voor het huidige project is dat deze verschillende thema’s vaak gezien worden als overlappend. Er wordt bijvoorbeeld soms verondersteld dat we over één leersysteem beschikken dat verantwoordelijk is voor het vormen van associaties op een automatische, onbewuste manier die berust op bottum-up processen. Het tweede leersysteem wordt dan gezien als gedreven door hypothese toetsing en deductie, als resulterend in propositionele representaties die beschikbaar zijn voor bewuste processen, en als gebaseerd op top-down processen.

Het voorgestelde onderzoeksprogramma wil deze overlapping van dichotomieën in vraag stellen. In plaats van te veronderstellen dat associatief leren steeds gebaseerd is op onbewuste, automatische, en bottom-up

processen, en dat hogere-orde cognitieve leerprocessen steeds een bewust, automatisch, en top-down karakter hebben, stellen we voor dat leerprocessen voortdurend werkzaam zijn op alle cognitieve niveaus. Vanuit dit perspectief zijn de hersenen constant en op onbewust niveau aan het leren om te anticiperen op de gevolgen van acties op het eigen organisme, de wereld, en andere personen. Er is aanzienlijke evidentie voor het bestaan van een dergelijk voorspellend mechanisme in de menselijke hersenen. Dit idee vormt zelfs de kern van een Bayesiaans perspectief op informatie verwerking en van Friston's "free energy" principe dat stelt dat de hersenen constant trachten om de mate van verassing te minimaliseren of conflict trachten te anticiperen door het voorspellen van toekomstige activiteit.

Binnen dit perspectief willen we ons toespitsen op de volgende drie centrale lijnen van onderzoek:

Het eerste onderzoeksthema heeft betrekking op computationele mechanismen en de neuronale correlaten van associatieve en hogere-orde leerprocessen, inclusief de interactie tussen deze processen. Een eerste reeks van vragen betreft de het voorkomen en de beperkingen van elk type leerprocessen. Hebben associatieve leerprocessen voldoende vermogen om een verklaring te bieden voor alle vormen van leren? Mensen en dieren delen een gelijkaardige neuronale organisatie, maar er zijn ook veel verschillen, vooral wat betreft het vermogen van mensen om via taal symbolische structuren met elkaar te delen en te leren via instructies. Langs de andere kant is er ook evidentie voor de rol van symbolische, propositionele structuren in het leren door niet-menselijke dieren. Een tweede reeks vragen betreft de dynamiek van de overgang tussen associatieve en hogere-orde leerprocessen (vb., inzicht; de invloed van de slaap-waak cyclus in het consolideren van geheugensporen; de mechanismen van automatisatie in het leren van een vaardigheid). Het blijft dus een prangende vraag hoe men kan gaan van associatief, sub-symbolisch leren naar hogere-orde vormen van leren.

Het tweede thema dat in ons onderzoeksprogramma aan bod komt, is de relatie tussen bewustzijn en leren. Er blijft een intens debat bestaan over de mate waarin mensen kunnen leren zonder bewustzijn van het geleerde. Op dit vlak willen we systematisch de grenzen aftasten van wat onbewust geleerd kan worden. De rol die bewustzijn speelt in leren en de rol die leren speelt in het vormen van de inhoud van bewustzijn, zijn fundamentele maar alsnog onopgeloste vraagstukken. Zijn de processen die betrokken zijn in bewust en onbewust leren onderbouwd door dezelfde of verschillende neuronale structuren? Wat zijn de beperkingen van leren zonder bewustzijn? Wat is de invloed van hogere-orde bewuste processen op verondersteld lagere-orde fenomenen zoals conditionering en habituatie? Hoe karakteriseren we best de verschillen en gelijkenissen tussen leren door mensen en leren door dieren?

Een derde thema heeft betrekking op de invloed van top-down en bottom-up processen en hun interacties. Functies zoals executieve controle en aandacht worden meestal gezien als bewuste top-down processen maar er is ook evidentie voor onbewuste executieve controle. We zullen vooral nadruk leggen op het begrijpen van (1) hoe hogere-orde processen zoals redeneren, het volgen van instructies, en bewustzijn een invloed kunnen hebben op lagere-orde, associatieve vormen van leren en (2) de wijze waarop lagere-orde, onbewuste vormen van leren een invloed hebben op bewuste, intentionele verwerking zoals bij het maken van beslissingen of intentionele actie.

Deze onderzoekslijnen zullen uitgewerkt worden in een reeks van acht onderling verbonden werkpakketten die elk gericht zijn op het benutten van de expertise van de partners. Ons netwerk omvat experten met betrekking tot onderzoek rond bewustzijn (P1 ULB – Cleeremans), slaap en geheugen (P1 ULB – Peigneux), taalontwikkeling (P1 ULB – Content), geletterheid (P1 ULB – Kolinsky), associatief leren en evaluatieve conditionering(P2 UGent – De Houwer), intentionele actie en cognitieve controle (P3 UGent – Brass), associatief leren bij dieren en kinderen (P4 KUL – Beckers), en plasticiteit in visuele perceptie (P5 UCK – Rossion). Verder doet het netwerk beroep op de expertise van twee buitenlandse partners: Prof. Patrick Haggard (INT1, University College London) voor zijn kennis rond vrije wil en intentionele actie, en Prof. Zoltan Dienes (INT2, University of Sussex) voor zijn expertise rond impliciet leren en onbewuste processen. De verschillende partners kennen elkaar zeer goed en hebben al vaak met elkaar samengewerkt. Ze delen niet enkel een fundamentele interesse in leren en plasticiteit binnen hun respectievelijke onderzoeksdomeinen maar beschikken ook over complementaire vaardigheden die ten volle benut zullen worden in het kader van dit onderzoeksprogramma. De bijdrage van elke partner aan het programma wordt onvoorwaardelijke gesteund door hun onderzoeksinstelling.

COOL is gestructureerd in acht werkpaketten die elk onder de verantwoordelijkheid vallen van één van de partners. Het voorgestelde onderzoek wordt gedreven door een coherent perspectief op hoe men de eerder beschreven dichotomieën dient te conceptualiseren. Het biedt een nieuwe aanpak van de fundamentele rol die bewuste en onbewuste leerprocessen spelen in verschillende fenomenen (vb., geheugen, waarneming van gezichten, perceptueel leren, taalvaardigheid, leren door dieren, conditionering, het maken van beslissingen, habituatie, impliciet leren, subliminale perceptie, vrije wil). Deze vernieuwende visie zal leiden tot een belangrijke stap voorwaarts in het begrijpen van de fundamentele vaardigheid van mensen en andere organismes om zich aan te passen aan een steeds veranderde omgeving.

RESUME DE LA PROPOSITION EN FRANCAIS

Titre de la proposition (20 mots maximum):

Mécanismes des apprentissages avec et sans conscience

Titre abrégé de la proposition (3 mots maximum):

Apprentissages avec et sans conscience

Résumé de la proposition :

L'objectif principal de ce projet est de contribuer à notre compréhension des mécanismes de l'apprentissage avec et sans conscience. L'apprentissage, c'est-à-dire la capacité de répondre de manière adaptée aux changements, est une habileté fondamentale pour tous les organismes. Grâce aux avancées récentes des méthodes d'imagerie cérébrale, il est maintenant devenu clair que le cerveau est un organe fondamentalement plastique dont l'architecture fonctionnelle est continuellement modifiée par l'expérience. Dans cette perspective, on pourrait dès lors défendre l'idée que l'apprentissage est une conséquence nécessaire du traitement de l'information : Nous apprenons tout le temps, qu'on le veuille ou pas. L'apprentissage peut prendre de nombreuses formes différentes. Par exemple, contrastez le fait d'apprendre que Steve Jobs vient de décéder avec le fait d'apprendre à réaliser les mouvements complexes du *flamenco*. Pensez aux différences entre apprendre à résoudre un problème arithmétique et apprendre une deuxième langue. Considérez les différences entre un bébé apprenant à marcher avec un adulte apprenant à jouer au tennis, ou les différences entre un rat apprenant à éviter un choc électrique avec un être humain apprenant l'histoire de la Guerre de Cent Ans.

Nous pouvons percevoir tant des similarités que des différences dans ces divers exemples. Tous impliquent des changements dans le répertoire comportemental et représentationnel des agents, mais ils semblent tous également faire appel à des processus fondamentalement différents. Une conséquence importante de cette diversité est que les recherches consacrées à l'apprentissage demeurent extrêmement morcelées en différents sous-domaines qui n'entretiennent que fort peu de liens entre eux. Par exemple, les recherches consacrées à l'apprentissage implicite — les processus via lesquels nous sommes capables d'apprendre de manière incidente et sans conscience des connaissances aquises, sont jusqu'à présent restées totalement déconnectées des travaux consacrés aux apprentissages conscients, de haut niveau, tels qu'impliqués dans le raisonnement causal ou dans la résolution de problèmes. De la même manière, les recherches consacrées aux mécanismes élémentaires d'apprentissage chez l'animal demeurent encore aujourd'hui fort éloignés des travaux consacrés à l'apprentissage chez l'homme.

En outre, le domaine reste fort controversé. Au moins trois controverses peuvent être ainsi identifiées. La première concerne la question de savoir dans quelle mesure l'apprentissage, en général, est enraciné dans des processus associatifs, dans des processus intentionnels impliquant une forme d'inférence, ou dans une combinaison des deux. Du point de vue expérimental, des données récentes (et controversées) ont indiqué que mêmes des animaux tels que des rats semblent capable de raisonner, remettant ainsi en cause une des présuppositions fondamentales des théories associatives de l'apprentissage. Conceptuellement, certaines théories du domaine présupposent que *tous* les processus d'apprentissage sont nécessairement enracinés dans des mécanismes associatifs (p. ex., le connectionisme) ; d'autres théories présupposent que tous les apprentissages impliquent nécessairement des processus de nature symbolique, et d'autres encore font l'hypothèse que les deux types de processus opèrent en parallèle ou qu'ils sont en compétition l'un avec l'autre.

La deuxième controverse concerne le rôle que joue la conscience dans l'apprentissage, et en particulier l'étendue et les limites de ce que l'on est capable d'apprendre sans conscience. La trosième controverse, enfin, concerne les rôles respectifs des processus « top-down » et « bottom-up » dans l'apprentissage et la

nature de leurs interactions (p. ex., des phénomènes tels que le conditionnement peuvent-ils être influencés par des processus de haut niveau ?). Crucialement, les pôles de ces différentes dichotomies sont souvent décrits comme nécessairement associés. On suppose donc qu'il existe d'une part un premier système capable d'apprendre de manière associative, automatiquement en l'absence de conscience, et via des processus « bottom-up », et d'autre part un deuxième système apprenant quant à lui via des processus inférentiels de type « top-down » produisant des représentations symboliques qui sont disponibles à la conscience.

Dans ce projet, nous proposons de reconsidérer fondamentalement cette distinction. En lieu et place de faire l'hypothèse que l'apprentissage associatif est nécessairement inconscient, automatique, et « bottom-up » et que l'apprentissage cognitif est nécessairement conscient, intentionnel et « top-down », nous proposons plutôt que les mécanismes de changement prennent place continuellement, à tous les niveaux de la hiérarchie cognitive, et à différentes échelles temporelles (au cours d'un essai, au cours d'un entraînement, au cours du développement). Dans cette perspective, le cerveau apprend continuellement et inconsciemment à anticiper les conséquences de son activité sur lui-même, sur le monde, et sur les autres agents. De nombreuses données expérimentales suggèrent aujourd'hui que de tels mécanismes prédictifs existent dans le cerveau. Cette idée constitué en réalité l'essentiel de la perspective Bayesienne sur le traitement de l'information et se trouve au cœur de la théorie de Friston (« the free energy principle »), selon laquelle le cerveau tente constamment de minimiser la « surprise » ou le conflit en anticipant sa propre activité sur base de représentations préalablement apprises qui font le lien entre action et conséquences de ces actions.

A partir de ce point de vue, nous proposons d'explorer trois directions de recherche principales, comme suit :

La **première direction de recherche** concerne les mécanismes computationnels et les corrélats neuraux qui sous-tendent les apprentissages associatifs et cognitifs, ainsi que leurs interactions. Un premier ensemble de questions concerne l'étendue et les limites de chaque type d'apprentissage. Les mécanismes d'apprentissage associatifs sont-ils assez puissants pour rendre compte de *tous* les apprentissages ? Les animaux et l'être humain partagent de nombreuses caractéristiques, mais diffèrent également substantiellement, en particulier par le fait que les derniers peuvent tirer parti de la puissance expressive du langage naturel afin d'utiliser et de partager des structures symboliques au travers de la culture de manière à être capables d'apprendre via des instructions, par exemple. A l'inverse, est-il possible de démontrer que des organismes jusqu'à présent considérés comme incapables de d'inférence peuvent cependant faire appel à des systèmes de représentation symboliques ? Un deuxième ensemble de questions concerne la dynamique qui sous-tend la transition entre les processus associatifs et les processus cognitifs (p. ex., l'insight, le rôle que joue le cycle veille-sommeil dans la consolidation, les mécanismes de l'automatisation dans l'apprentissage d'habilétés). La question de savoir comment s'effectue la transition entre processus associatifs, sous-symboliques et les processus cognitifs, symboliques, demeure aujourd'hui un véritable mystère.

La **deuxième direction de recherche** concerne les relations entre apprentissage et conscience. Cette question continue de susciter aujourd'hui des débats considérables, à propos en particulier de la question de savoir si les êtres humains sont capables d'appendre sans conscience dans des domaines tels que le conditionnement ou l'apprentissage implicite. Dans ce projet, nous comptons explorer systématiquement les limites de ce que l'on peut apprendre sans conscience. Le rôle que la conscience joue dans l'apprentissage, et inversement, le rôle que l'apprentissage joue dans la conscience, sont des questions fondamentales mais qui demeurent aujourd'hui sans réponse. Ainsi, les mécanismes impliqués dans les apprentissage avec et sans conscience sont-ils sous-tendus par les mêmes processus ou pas ? Quelles sont les limites de ce que l'on peut apprendre sans conscience ? Quelle est l'influence de processus conscients sur des phénomènes tels que le conditionnement ou l'habituation ? Comment caractérise-t-on les différences entre l'apprentissage chez l'animal (présumé inconscient) et chez l'homme ?

Une troisième direction de recherche, enfin, concerne les influences respectives des processus « top-down » et « bottom-up » sur l'apprentissage, ainsi que leurs interactions. Alors que des fonctions de haut niveau telles que le contrôle exécutif ou l'attention sont typiquement considérées comme étant associées à la conscience, il y a maintenant des données expérimentales qui suggèrent la possibilité d'un contrôle exécutif sans conscience, ainsi des données suggérant que l'attention peut être dissociée de la conscience. Nous explorerons ici en particulier (1) comment des processus de haut niveau tels que le raisonnement, le fait de suivre des instructions, et la conscience peuvent moduler des processus élémentaires d'apprentissage associatif, et (2) comment ces mêmes processus d'apprentissage associatif peuvent à leur tour influencer le traitement conscient, intentionnel, comme par exemple dans la prise de décision ou l'action.

Ces différentes directions de recherche seront développées au travers d'une série de huit modules de travail qui sont spécifiquement conçus pour engager les domaines d'expertise respectifs des différents partenaires du réseau. Le réseau comporte des experts dans les domaines de la conscience (**P1** ULB—Cleeremans), du sommeil et de la mémoire (**P1** ULB—Peigneux), du développement du langage (**P1** ULB—Content), de la litéracie (**P1** ULB—Kolinsky), des processus d'apprentissage associatifs et de conditionnement évaluatif (**P2** UG—De Houwer), de l'action et du contrôle cognitif (**P3** UG—Brass), de l'apprentissage chez l'animal (**P4** KUL—Beckers) et de la vision et de la perception (**P5** UCL—Rossion).

En outre, le réseau à fait appel à deux experts internationaux : Le Pr. Patrick Haggard (**INT1** , University College London), pour son expertise concernant la volonté et l'action, et le Pr. Zoltan Dienes (**INT2** , University of Sussex), pour son expertise concernant l'apprentissage implicite et les processus inconscients. Les partenaires se connaissent bien et ont déjà souvent eu l'occasion de collaborer ensemble. Ils partagent non seulement un intérêt profond pour l'importance des processus d'apprentissage et de plasticité neuronale dans leurs domaines respectifs, mais peuvent également faire état de compétences et de domaines d'expertise complémentaires. Tous ont d'ores et déjà obtenu le soutien des leurs institutions respectives.

COOL est structuré en huit modules de travail. Chaque module de travail est placé sous la responsabilité d'un des partenaires. Les recherches proposées sont sous-tendues par une perspective nouvelle et cohérente à propos de la manière dont il s'agit de réinventer les dichotomies traditionnelles décrites ci-dessus, et porteront sur le rôle fondamental que jouent les processus d'apprentissage conscients et inconscients dans différents domaines (la mémoire, la perception des visages, l'apprentissage perceptuel, la litéracie, l'apprentissage chez l'animal, le conditionnement, la prise de décision, l'habituation, l'apprentissage implicite, la perception sublimale, la volition). La perspective innovante que nous défendons produira sans aucun doute une avancée substantielle dans notre compréhension des mécanismes fondamentaux via lesquels les être humains et d'autres organismes sont capables de s'adapter à un environnement changeant constamment.

BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 • Fax +32 2 230 59 12
www.belspo.be

belspo

Interuniversity Attraction Poles (IAP)
Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION IV (optional)

Declaration of intent of the international partner and its institution for the co-financing

To be completed by the international partner (one form per partner)

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words) : Mechanisms of conscious and unconscious learning
Proposal's acronym : COOL
Name of the international partner: Patrick Haggard Institution: University College London

Code (Reserved for BELSPO) :

.be

DECLARATION OF INTENT OF THE INTERNATIONAL PARTNER AND ITS INSTITUTION FOR THE CO-FINANCING

Institution's name : University College London
Institution's address :
Road/Street , n° : Gower St
Postal code : WC1N 3AR
Town/City : London
Country : uk
Name of the contractor for the Institution [1] : EVA FARACE

Name of the international partner [2] :Patrick Haggard
Title : (Prof., Dr.) Prof
Name of the research unit :Institute of Cognitive Neuroscience
Address :
Road/Street, n° : Queen Square, 17
Post code : WC1N 3AR
Town/City : London
Country : UK
Tel. :0207 679 1153
E-mail address : p.haggard@ucl.ac.uk

We, the undersigned, hereby declare our interest in participating in the proposed network as international member of the network, and to co-fund our participation to the tune of 50%.

Date :

Signature of the international partner :

Signature of the contractor for the Institution :

[1] Person who can contractually bind an institution e.g. the rector in case of an university.
[2] Should be the same as in Section I – Form A.

BELGIAN SCIENCE POLICY OFFICE

Louizalaan 231 avenue Louise
B-1050 BRUSSELS
Tel. +32 2 238 34 11 • Fax +32 2 230 59 12
www.belspo.be

belspo

Interuniversity Attraction Poles (IAP) Phase VII

2012 - 2017

Call for proposals

Submission form - SECTION IV (optional)

Declaration of intent of the international partner and its institution for the co-financing

To be completed by the <u>international partner</u> (one form per partner)

Closing date: 17 October 2011 at 12:00 (noon)

Proposal's title (maximum 20 words) : **Mechanisms of conscious and unconscious learning**
Proposal's acronym : COOL
Name of the international partner: Zoltan Dienes Institution: University of Sussex

Code (Reserved for BELSPO) :

.be

DECLARATION OF INTENT OF THE INTERNATIONAL PARTNER AND ITS INSTITUTION FOR THE CO-FINANCING

Institution's name : University of Sussex
Institution's address :
Road/Street , n° : Sussex House
Postal code : BN1 9RH
Town/City : Brighton
Country : UK
Name of the contractor for the Institution [1] : Rossana Dowsett

Name of the international partner [2] :Zoltan Dienes
Title : (Prof., Dr.) :Prof
Name of the research unit :School of Psychology
Address :
Road/Street, n° : Pevensey Building
Post code : BN1 9QH
Town/City : Brighton
Country : UK
Tel. :01273 877335
E-mail address : dienes@sussex.ac.uk

We, the undersigned, hereby declare our interest in participating in the proposed network as international member of the network, and to co-fund our participation to the tune of 50%.

Date : 7 October 2011

Signature of the international partner :

Signature of the contractor for the Institution :

Rossane Dowsett
Head of Research Development
Research & Enterprise Services

[1] Person who can contractually bind an institution e.g. the rector in case of an university.

[2] Should be the same as in Section I – Form A.