**Interuniversity Attraction Poles (IAP)—Phase VII**

# COOL

## "Mechanisms of conscious and unconscious learning"

**2nd Annual Report P7/33**
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# TABLE OF CONTENTS

# 1. ABBREVIATIONS

| | |
|---|---|
| **ULB** | Université Libre de Bruxelles |
| **UCL** | Université Catholique de Louvain |
| **KUL** | Katholieke Universiteit Leuven |
| **UG** | Universiteit Gent |
| **UCLondon** | University College London |
| **USussex** | University of Sussex |

# 2. NETWORK COMPOSITION

| | | |
|---|---|---|
| **P1a** | **Pr. Axel Cleeremans**<br>*axcleer@ulb.ac.be*<br>**Coordinator** | Université Libre de Bruxelles<br>Center for Research in Cognition & Neurosciences – CO3<br>50 ave. F.-D. Roosevelt CP191<br>B1050 Bruxelles<br>BELGIUM |
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# 3. INTRODUCTION

P7/33 « Mechanims of Conscious and Unconscious Learning » was initiated on 01/10/2012. **The overarching goal of the 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. 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. In this project we 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.

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 are 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 (**P1a** ULB—Cleeremans), on sleep and memory (**P1a** ULB—Peigneux), on language development (**P1b** ULB—Content), on literacy (**P1b** ULB—Kolinsky), on associative learning and evaluative conditioning (**P2a** UG—De Houwer), on intentional action and cognitive control (**P2a** UG—Brass), on animal learning (**P3** KUL—Beckers) and on vision and perception (**P4** 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.

As a general commentary, the network, after approximately two years of operation, is now working as planned: All partners are now fully engaged in active collaboration, leveraging their highly complementary skills, the combination of which will be essential to carry out the proposed research. The project involves available methods of cognitive neuroscience, from animal work, electrophysiology and brain imaging to behavioural methods and computational modelling.

The network held two very successful meetings over its first year of operation, as well as a substantial number of smaller meetings involving only some of the partners and dedicated to plan future experiments. Junior members of the network (Ph.D. students and post-docs) are fully engaged. As described below, the network was also very active during its second year of operation (2014), with another successful general meeting organized in Leuven as well as numerous smaller workshops and informal encounters during the year.

Since its inception, the network has produced about **40** publications in peer-reviewed journals (including four co-publications that involve distinct teams), and many more conference presentations and posters that are not described in this annual report.

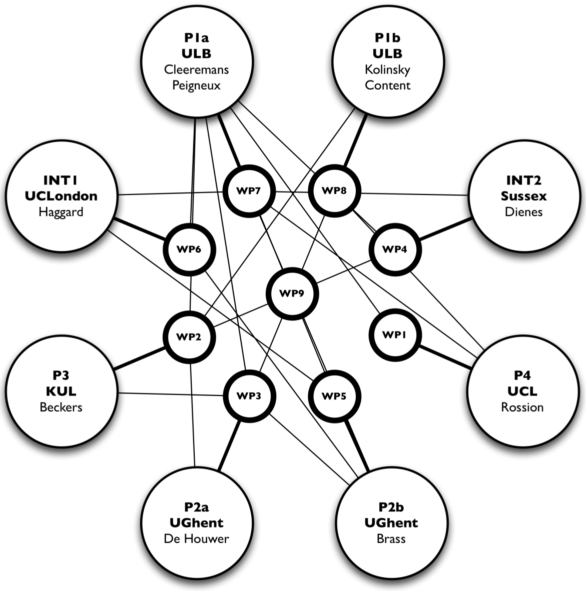
# 4. DESCRIPTION OF COMPLETED RESEARCH

As depicted in Figure 1, 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. Each is under the responsibility of one of the partners, and all involve the cooperation of several teams.

The nine WPs are as follows:

In **WP1**, **P4** (UCL—Rossion) and **P1a** (ULB—Peigneux) (ULB) collaborate to explore the neuro-functional mechanisms of conscious and unconscious memory acquisition, as well as post-training consolidation for novel faces.

In **WP2**, **P3** (KUL—Beckers), **P2a** (UG—De Houwer) and **P1** (ULB—Cleeremans, Peigneux & Kolinsky) 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 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.




**F1:** Each of nine Work Packages is under the responsibility of a Lead Partner. Each participating team is involved in different work packages.

**WP3**, carried out by **P2a** (UG—De Houwer) in collaboration with **P1a** (ULB—Cleeremans), **P2b** (UG—Brass) and **P3** (KUL—Beckers), explores the properties of conditioning and habituation via verbal instructions.

**WP4** led by **INT2** (USussex—Dienes) in collaboration with **P1a** (ULB—Cleeremans) and **P3** (KUL—Beckers), explores (1) whether learning can take place with subliminal stimuli, and (2) whether abstract concepts such as symmetry can be learnt implicitly.

**WP5**, led by **P2b** (UG—Brass), in collaboration with **P1a** (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 **P1a** (ULB—Cleeremans) and **P2b** (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 **P1a** (ULB—Cleeremans) in collaboration with **P2b** (UG—Brass), **P4** (UCL—Rossion), **INT1** (UCLondon—Haggard) and **INT2** (USussex—Dienes), explores, 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 **P1b** (ULB—Kolinsky & Content) in collaboration with **P4** (UCL—Rossion) and **P2a** (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.

In the following, we provide a progress report about the ongoing research carried out to fulfill the objectives of each WP.

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

**Lead Partner: P4** (UCL – Rossion)
**Associated teams: P1a** (ULB – Peigneux & Cleeremans)

The objective of this work package 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, all our life, and can be considered as an excellent instance 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 (identity, sex, mood, …). Distinguishing individual faces, in particular, requires elaborate and refined perceptual skills call for by few other categories of objects, so that the face is a fantastic category of stimulus to study perceptual learning (Gilbert et al., 2001). Adults attain a high degree of proficiency with these skills, as evidenced by the capacity to identify a person in less than a second (Ramon et al., 2011) despite the similarity among faces. 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, while there is a very large amount of work devoted to understanding how humans *perceive* faces (see Calder et al., 2011), the factors and dynamics subtending the creation of novel face representations in the human brain are scarcely studied. This work package will take advantage of the joint expertise of B. Rossion (UCL) in face perception and P. Peigneux (ULB) in mechanisms of learning and memory to explore the neuro-functional mechanisms of memory acquisition and post-training consolidation for novel faces and objects.

The research carried out since the beginning of this project has consisted in:

- The development of a new set of visual shapes ("the pinguins"), in collaboration with Q. Vuong and V. Willenbockel (Newcastle University, UK). The set is developed in 3D studio max and corresponds to 10 prototype shapes with 5 diagnostic parts. From these propotypes, sets of stimuli that are quasi-conjunctive are created: like faces, the individuals cannot be recognized by a single part because single parts are too similar to each other across exemplars. Recognition has to be based on a conjunctive analysis of the parts, and the goal of the extensive training is test whether one can develop holistic (i.e. integrated) representations of these objects, and if so whether these representations can compete with the representation of faces, both at the behavioural and neural levels. In the stimulus set, prototypes can be morphed with each other to create intermediary stimuli whose physical distance can be quantitatively defined. This first set of almost an infinite number of stimuli provides an excellent resource for this work package but also for other work packages of the network.
- The development a full training program for extensive training (16-20 hours) to learn individual exemplars of these objects (verification tasks, naming, visual search, card sorting tasks, etc.).

- The running of 20 participants in a learning study, with pre- and post-test behavioural and electrophysiological measures of learning. The study shows for the first time that learning a larger set of individual 3D shapes with multiple parts modulates the visual representation of new exemplars of this set. This is demonstrated by a significant increase of a visual discrimination response over the lateral occipital cortex (bilaterally), post-training, during an implicit task. The discrimination measure is obtained thanks to a fast periodic oddball paradigm in EEG, providing robust visual discrimination responses in a few minutes (Liu-Shuang et al., 2014). However, this effect is found only if the 3D shapes have a facelike configuration, not if the exact same shapes are learned upside-down. Thus, there is both evidence for brain plasticity (changes in visual representation following training), and for resilience or rigidity of the system (no effect on visual representation for nonface like shapes). Since both kinds of shapes are learned behaviourally, this raises the issue of the different mechanisms at play. An abstract has been sent for a presentation at the next meeting of the Vision Science Society (2015, May) and a paper is in preparation (Lochy et al.).
- A full replication of an early study in which participants learn inverted faces and show a reduction of their face inversion effect (Laguesse et al., 2012). In this new study, in addition to behaviour, EEG measures of individual discrimination using the FPVS oddball paradigm are taken before and after training. The data is currently being analyzed but tend to show an increase in the visual discrimination response for both inverted and upright faces, with a larger increase for inverted faces, showing that as long as the stimulus is interpreted as face, learning can change the visual representation.
- The development of a short implicit learning program of individual faces in order test whether familiar vs. unfamiliar discrimination responses can be obtained in EEG using the FPVS approach (L. Quenon).

## WP2 — Mechanisms of conditioning and causal learning

**Lead Partner: P3** (KUL – Beckers)
**Associated teams: P2a** (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 two lines of research, we aim to challenge these fundamental assumptions with respect to animal conditioning (WP2a) and children's causal learning (WP2b). In a complementary line of research (WP2c), we are investigating the inverse claim that under some circumstances, conditioning can take place in the complete absence of awareness in adult humans — an even more controversial topic.

**WP2a: Animal conditioning as active inference-making.** In WP2a, we pursue the idea that seemingly basic associative learning phenomena may reflect sophisticated causal inference skills in animals. That theme is investigated through a diverse set of studies. In a first series of experiments, we have been aiming to investigate whether rats can learn to solve discrimination problems that involve an abstract rule (positive and negative patterning; i.e., cues that signals the absence of reward when presented alone, signal the availability of reward when presented in compound, whereas cues that signal the availability of reward when presented individually, jointly signal the absence of reward) and whether they will show transfer of that rule to novel sets of stimuli / novel discrimination problems. Our research indicates that rats can learn to solve the (seemingly rule-based) patterning problems, but will not apply the underlying patterning rules to novel stimuli. That result suggests that the animals solve the patterning problems by reliance on non-rule-based principles (i.e., configuring). Under comparable conditions, humans do show transfer. Ascertaining that was important, because in previous research, humans have demonstrated rule-based transfer but have typically been trained on multiple patterning problems before testing transfer. The results of those experiments have meanwhile been submitted for publication (Maes et al., 2014). A second series of experiments has been aimed at replicating the blocking effect, a hallmark phenomenon of Pavlovian conditioning in animals (see proposal for details), with the ultimate aim of evaluating whether it is modulated by training rats on non-linear integration problems. Unfortunately, across an extensive series of experiments in different strains of rodents and using a variety of procedures, we have been unsuccessful in obtaining a solid blocking effect. We are currently preparing a manuscript about that series of replication failures and its implications for theories of associative learning (Maes et al., in preparation). Meanwhile, we have started a new series of studies that probe the generalization of patterning rules in rats using a touchscreen procedure, which allows to present multiple instances of patterning problems before proceeding to generalization testing.

In a related line of work, we are investigating whether the human capacity for symbolic cognition has precursors in rats. More specifically, we are probing the reasons for the observed failure of animals to demonstrate symmetry. Symmetry refers to the observation that if humans learn that a stimulus A is in some meaningful way related to a stimulus B, so that presenting stimulus A leads to activation of the representation of B, they can reverse that relation so that presenting stimulus B will also activate the representation of A. A standard procedure to investigate symmetry is the matching-to-sample procedure, in which subjects have to learn to choose the appropriate target stimulus from a series of distractors upon presentation of a sample stimulus (e.g., upon presentation of A, when presented with the choice between B and C, choose B). After learning to choose B in the presence of A, humans will readily come to select A rather than D in the presence of B. Animals consistently fail to demonstrate such transfer. We are investigating whether the lack of symmetry may be linked to intrinsic aspects of the matching-to-sample task rather than a fundamental incapacity for symmetry in rats. In a first study, we investigated whether multiple location training would facilitate the generalization of identity matching (learning to select A above B when first presented with A as a sample). Our results suggest that, although rats are capable of learning generalized identity matching, varying the locations of sample and target stimuli does not enhance their performance, tentatively ruling out stimulus-location configuring as a cause for failure to observe symmetry in rats. A manuscript on those results is almost ready for submission (Beurms et al., in preparation). In another experiment, we have employed a new methodology, loosely based on Pavlovian-to-Instrumental Transfer (PIT), to assess the trainability of symmetry in stimulus-outcome learning in rats. A first experiment has yielded tentative support for symmetry in rats (i.e., when primed with a sensory stimulus that was previously the result of a particular response, rats tended to perform that response more readily than an alternative response). We are currently trying to replicate that observation, while also setting up related experiments in humans where we try to replicate alleged demonstrations of symmetry in pigeons, to evaluate whether the observation of symmetry in pigeons relies on the same mechanisms as it does in humans.

**WP2b: Developmental aspects of causal learning.** In WP2b, we are following up on recent work that we did that revealed that the development of causal learning goes hand in hand with the development of particular inferential reasoning and working memory abilities (e.g., McCormack et al., *Journal of Experimental Child Psychology*, 2013). For this, we want to probe the developmental trajectory of Pavlovian-to-Instrumental Transfer (PIT) in children. A first study, conducted in early 2014, demonstrated the basic PIT effect in adults (both selective PIT, which arguably reflects the association of cues and responses with the sensory aspects of an outcome, and non-selective PIT, which reflects the association of cues and responses with the emotional-motivational properties of an outcome). A second study investigated the sensitivity of selective and non-selective PIT to extinction of the association between cues and outcomes; the results of that study are currently being analysed. We hope to include both studies in a manuscript to be submitted for publication in 2015. Meanwhile, we are setting up a first study to probe selective and non-selective PIT in children of various age groups, to be conducted in spring 2015.

**WP2c: Learning novel associations outside awareness during sleep.** Studies described in the above packages aimed at investigating 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. In part, these lines of research raise the crucial question of the contribution of controlled and automatic processes in learning. In the present work package, we extended this questioning in asking whether the human brain learn novel information at all in the absence of consciousness or awareness. In this respect, sleep is a model of non-awareness, and creation of novel associations during controlled states of sleep would be a conclusive demonstration of unconscious learning abilities. After conducting studies in 2013 et 2014 showing that cueing in the awake state modulates memory retention for emotional material (Gilson and Peigneux, 2013), we are currently investigating the effect of cueing emotional material during sleep on subsequent memory consolidation using EEG recordings, psychophysiological and behavioural measures (Gilson and colleagues). We have also developed novel measures of emotional reactivity and its changes after sleep or wake using skin conductance, and found associations with REM sleep parameters (Gilson, Bodart, Deliens, Leproult, Nonclercq, Ercek and Peigneux, in preparation). We have also developed a non-invasive procedure allowing the assessment of auditory statistical learning by magnetic frequency tagged responses, adapting a steady-sate approach to magnetoencephalographic (MEG) recording. After obtaining conclusive results at wake (Farthouat, Op de Beeck, Mary, Delpouve, Leproult, Franco, de Tiège & Peigneux, in preparation), we are now testing auditory statistical learning during sleep in young healthy adults. In other work, conducted in collaboration between ULB and KU Leuven, we aim to investigate how sleep affects learning. In one experiment, we assessed whether sleep affects the generalization of learned fear responses. It is of note that fear generalization is the core aspect of what makes anxiety disorders so impairing: Fear does not remain specific to a single stimulus paired with danger but generalizes to a broad set of stimuli. A war veteran might, for instance, start to respond fearfully to anything remotely sounding like a gunshot. The currently dominant laboratory model for gaining insight in fear generalization is the human fear conditioning paradigm. In this paradigm, all subjects receive paired presentations of an initially neutral stimulus (the Conditional Stimulus or CS; say an image of a circle) and an intrinsically aversive stimulus (the Unconditional Stimulus or US; say, an electrocutaneous stimulus). Crucially, to assess generalization in the test phase, fear is measured in response to an array of stimuli that are similar to but different from the original CS (e.g., larger or smaller circles). In our experiment, sleep between original learning and generalization testing was experimentally manipulated: Participants did sleep in between, did not sleep in between, or were actually deprived of nighttime sleep. Surprisingly, the results of this study did not reveal any difference between conditions. We are therefore currently running a study in which we are replicating this study with stimulus material that might be more sensitive to the sleep manipulation. In addition, we have just finished data collection on the effects of sleep deprivation on learning in a blocking procedure, another procedure that can be used to model generalization and selectivity of fear learning. The data of this study will be analyzed in the coming months.

In another series of experiments, we are investigating the effect of sleep and sleep deprivation on reversal learning. In one experiment, in a first phase, we paired one CS with the US, while a second CS was presented without US. In a second phase, we reversed these contingencies: The first CS was now presented without US and the second CS with US. We observed that a night of sleep deprivation slows down the reversal learning in the second phase. We are currently replicating this experiment and a manuscript will be written and submitted if these results stand the test of replication. In addition, we are currently investigating whether cognitive fatigue (i.e., an "ego depletion" manipulation) affects reversal learning in a similar way as actual sleep deprivation.

## WP3 — Mechanisms of Learning via instructions

**Lead Partner: P2a** (UG – De Houwer)
**Associated teams: P1a** (ULB – Cleeremans), **P2b** (UG – Brass) and **P3** (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 contrast, in this WP we maximize the role of high-level mental processes by focusing on learning via instructions. 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 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.

**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 aim to 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).
At the start of the project, Marcel Brass and Jan De Houwer were involved in a study to test the extent to which experience adds to the effect of instructions in fear conditioning. A paper based on this research has now been published the open access journal PLoS ONE (Raes et al., 2014). Gaëtan Mertens was hired as a PhD student to conduct behavioral work on this topic within the context of the IAP. He replicated the Raes et al. study using an additional dependent variable that is supposed to capture low level processes (i.e., startle potentiation). A paper describing this study has been submitted for publication. In two additional studies, Gaëtan studied the impact of the fear-relevance of the CSs on instructed fear conditioning. In both studies, he found instructed fear conditioning independent of the fear-relevance of the CS, a result that was replicated in a condition with experience-based fear conditioning. Interestingly, the studies also provided the first evidence for reinstatement effects in instructed fear conditioning (i.e., the fact that the presentation of a US after successful extinction reestablishes the conditioned response). A paper describing these studies is currently being written. More recently, Gaëtan completed a study on context switch effects and context instructions in a verbal fear conditioning procedure, showing a instructed fear conditioning depends on information about when the instructions are said to be valid. He also collected data on the reversal of instructions (i.e., does fear switch when contingencies are set to switch) and early EEG indicators of instructed fear conditioning. Finally, Marcel Brass, Senne Braem, and Jan De Houwer have implemented the paradigm of Raes et al. (2014) using fMRI. A first draft of a paper about this study has been completed.

**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. Gaëtan Mertens and Jan De Houwer examined for the first time mere exposure via instructions. Participants were told that one stimulus would occur more often than another stimulus. In six consecutive studies, we observed that the stimulus which was said to occur more often was liked more by the participants than the stimulus who was said to occur infrequently. Marcel Brass, Wouter De Baene, and Jan De Houwer have developed a procedure to test habituation via instructions using fMRI. Initial data failed to show an effect of instructions, raising the question of whether such effects might be found under other conditions (e.g., after mental practice).

## WP4 — Mechanisms of implicit learning

**Lead Partner: INT2** (Sussex – Dienes)
**Associated teams: P1a** (ULB – Cleeremans) and **P3** (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 WP4 thus correspond to the two main issues that define the field.

Substantial work has been achieved on the two objectives. Solid evidence for (1) was achieved last year, as described in the report for that year. We have just submitted a further paper showing implicit learning of subliminal stimuli in a different way 9specifically implicit learning of cross modal associations of subliminal stimuli, challenging strong versions of global workspace theory); this can be expected to be published in 2015 and so will appear in next year's report. In terms of (2), as reported last year, Li et al (2013) found that when two types of mirror symmetries defined the abstract structure of successive lines of Chinese poetry, both mirror symmetries were learnt unconsciously. That is, people could tell if poetry had the same structure as they were just exposed to, but they couldn't say what that structure was, and they believed they were literally guessing or using intuition to make their judgments. People were responsive to symmetry even though chunks and repetition patterns were controlled. As chunks and repetition patterns correspond to what we already know can be implicitly learnt, the demonstration of learning symmetries challenges existing computational models of implicit learning. That was last year; this year we have first drafts of two papers showing that an SRN connectionist model can simulate these results. These two papers are also expected to be published in 2015 and so will appear in next year's report.

Having achieved the objectives laid out for this work package, we have begun work linking to **WP6**, i.e. relating to the topic of a sense of conscious agency. A summary of the work conducted this year had the opportunity to be rapidly published in a book chapter, Dienes et al (in press). The work will also appear in journal articles, some of which can be expected to come out in 2015. The new work on agency uses higher order thought theory, which had been the basis for establishing unconscious knowledge in Li et al (2013). In the new work higher order thought theory is applied to hypnosis and mindfulness. A theme among many theories of hypnosis is that hypnotic response is a form of strategic self-deception about what mental state one is in (e.g. Dienes & Perner, 2007; E. R. Hilgard, 1977; Spanos, 1986). By contrast, a theme for many meditation practices is that they involve and cultivate mindfulness; and mindfulness, where it succeeds, involves being aware of the mental states one is in. Thus, by this argument, hypnotic response implies a lack of mindfulness, at least for those particular mental states about which one is strategically deceived. This last year we have investigated the postulated tension between hypnotic response and mindfulness using the Libet paradigm to look at awareness of intentions. Consistent with theory, we found that highly hypnotisable people were especially late in their awareness of intentions, and mindfulness meditators especially early. Further, using the intentional binding paradigm of partner **INT1** (Patrick Haggard, UCL), we also found that meditators had especially strong intentional binding.

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

**Lead Partner: P2b** (UG – Brass)
**Associated teams: P1a** (ULB – Cleeremans & Peigneux) and **INT1** (UCL – Haggard)

The aim of work package 5 is to investigate the interaction of top-down and bottom-up factors on intentional control of action. Starting October 2013, Martijn Teuchies has been working as a PhD student in Ghent with Marcel Brass on the topic of WP5. During the past year the first experiment on decision making has been carried out in Ghent in collaboration with Nura Sidarus, a PhD student with Patrick Haggard in London. This experiment aimed at the first part of the project in which we investigate how bottom-up factors affect decision making.

To test the influence of bottom-up factors, a response priming paradigm was used in this experiment to bias free decisions. This paradigm has been used before by Nura Sidarus and in collaboration with her we fine-tuned the paradigm for use in the fMRI scanner. In this paradigm participants have to respond to target stimuli (arrows) with either the left or the right hand. On some trials choices will be forced (i.e. they will have to respond left or right depending on the direction of the arrow). On other trials free choices have to be made (i.e. the target arrow is pointing both ways). Smaller, subliminally presented (for only 17 ms) arrows will precede the target arrows, thereby influencing free choices in an unconscious way. First, several behavioral pilot experiments were carried out in January and February 2014 to assure that the response priming paradigm yielded the expected results. Next, in April and June 2014, fMRI data has been collected for 30 participants. These data have been analyzed using a classical general linear model analysis (GLM) and we are currently starting to use a relatively new analysis method called multi-voxel pattern analysis (MVPA). Using MVPA we want to predict decisions from brain activity before participants become aware of the decision. This way, we can learn more about how the decision making process evolves on the brain level and how bottom-up influences bias decisions.

This first experiment served as a starting point to develop and carry out further experiments in **WP5** on decision making. In the coming year a follow-up experiment will be carried out in collaboration with **P1a** (Axel Cleeremans, ULB). The response priming paradigm will be combined with a placebo-suggestion manipulation using sham tDCS (see e.g. Magalhães De Saldanha da Gama, Slama, Caspar, Gevers, & Cleeremans, 2013). We plan to apply sham tDCS to the pre-frontal cortex and tell participants their ability to make free decision will be impaired. This experiment will aim at the second part of the project in which we will further investigate the interaction between the unconscious processing of bottom-up information and higher order top-down processes.

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

**Lead partner: INT1** (UCL – Haggard)
**Associated teams: P1a** (ULB – Cleeremans) and **P2b** (UG – Brass)

The sense of agency refers to the feeling that we can control our actions and, through them, events in the outside world. This is a fundamental feature of human mental life, but the mechanisms underlying this experience are still poorly understood. Many studies have shown that an important aspect of the sense of agency depends on the learning of instrumental relation between an action and its outcome. This enables the brain to produce predictions of action- outcomes and compare these with actual outcomes. Yet, this mechanism can only be used after the outcome is known, and thus supports a *retrospective* process that informs the sense agency. Importantly, recent studies (e.g. Chambon, Wenke, Fleming, Prinz, & Haggard, 2013; Wenke, Fleming, & Haggard, 2010) have shown that processes related to action selection can *prospectively* inform agency. By subliminally priming left/right hand actions, it was shown that participants reported a stronger sense of agency over outcomes that followed compatibly primed, compared to incompatibly primed, actions. This suggests that the sense of agency is also based on an experience of how we select what to do, and not only on monitoring the outcomes of our actions.

WP6 has focused on exploring the role of these prospective and retrospective cues in the conscious experience of agency. A critical question is whether these two mechanisms have independent effects on agency, or whether the efficiency of action selection might influence outcome monitoring processes. We addressed this in a study conducted this year by investigating whether the electrophysiological correlates of action selection and outcome monitoring processes were related to explicit judgements of agency. Our results showed that while subliminally priming actions affected action selection processes, it did not affect outcome monitoring. Moreover, we found that processes related to action specification, i.e. making a left vs. right hand action, were correlated with agency judgements. Interestingly, processes that monitor conflict in response selection were shown to be sensitive to action priming but not agency. Finally, outcome monitoring processes were also correlated with agency judgements. In short, this first study suggests that prospective and retrospective mechanisms have independent effects on the conscious experience of agency.

A new electrophysiological study into the neural correlates of agency corroborated our previous finding of an independent contribution to the sense of agency of prospective and retrospective cues. Subliminal action priming affects the subjective experience of agency independently of outcome processing. It also replicated the finding that outcome monitoring processes were correlated with agency judgements. The fMRI study run in collaboration with Ghent has been completed, and is currently being analysed.

A series of studies was conducted using a new experimental paradigm to assess the role of awareness in the effects of action selection processes on agency. The Eriksen flanker task was used to manipulate action selection, similarly to priming, but with conscious stimuli. Our results showed that conflict in action selection still led to a reduction in the sense of agency, even though participants were aware of the cause of that conflict. Therefore, the contribution of action selection processes to the experience of agency is independent of the role of awareness of bias- or conflict- inducing stimuli.

Next steps include:

1. A research visit to Columbia University by Nura Sidarus will focus on developing paradigms of high ecological validity to investigate prospective cues to the sense of agency.
2. The design and implementation of an experimental investigation of altered action awareness under hypnosis, in collaboration with Cleeremans (**P1a)** and Dienes (**INT2**).
3. The collection of neurophysiological measures of embodied agency (in collaboration from Emilie Caspar, **P1a**).

## WP7 — Mechanisms of awareness: Learning to be conscious

**Lead Partner: P1a** (ULB – Cleeremans)
**Associated teams: P2b** (UG – Brass), **P4** (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, it consists of three interlocked but different subprojects. **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.

Concerning **WP7a**, focused on quality of representation, we carried out several experiments aiming at testing the core hypothesis that availability 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. In a first experiment corresponding to **Study 7a.1a**, we used Marcel (1983)’s prime repetition procedure to find out whether repeating an (invisible) prime up to 20 times increases priming without increasing visibility. Marcel found that such repetition indeed increases priming without increasing availability to conscious report. However, contemporary neural theories of consciousness predict the opposite: Increasing bottom-up strength in such a priming paradigm should also result in increasing availability to awareness. Our results did not replicate the dissociation observed in previous studies and are instead suggestive that repeating an unconscious and attended masked stimulus enables the progressive emergence of perceptual awareness. In other words, we found a systematic correlation between the size of the priming effect and the extent to which people reported having seen the stimulus (using the graded PAS scale developed by Overgaard and colleagues). These results are now reported in a publication (Atas et al., 2013). Further studies explored the dynamics of priming effects (Atas et al., 2014b, 2015).

In a further line of research, we also established that people can become sensitive to the sequential regularities contained in sequences of invisible stimuli. This work used gaze-contingent crowding, a powerful method to ensure that the stimuli remain invisible. The study lends support to the idea that sequence learning can take place in the absence of awareness, thus demonstrating unconscious learning. The study was published (Atas et al., 2014a).

A second line of research (**Study 7a.1c)** in the context of WP7a consisted of manipulating the distinctiveness of stimuli. Following Archambault et al., we manipulated 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. Hence we used greebles and fribbles, artificial visual stimuli developed by Tarr and Gauthier. Participants were first exposed to these stimuli in a psychophysical design to obtain a baseline and they were trained (over three successive days) to associate names with some of the items. Next, all participants were again exposed to the named and unnamed stimuli in a psychophysical design. We did find effects of training: People become better at recognizing invisible stimuli after extended training. However, different aspects of this study make the results somewhat difficult to interpret. We plan on carrying out a conceptual replication of this study using better stimuli developed by **P5**.

In a further experiment carried out in the same spirit, we asked about the effects of existing expertise on visual awareness (**Study 7a.2a)**. Thus, instead of training participants in a novel domain, we compared populations with different expertise. To do so, we compared the performance of Chinese and European participants on identifying Chinese vs. Maya symbols, and asked them to rate the visibility of each stimulus, again presented in a psychophysical design (16ms — 216ms). The results indicated superior performance and better visibility ratings for Chinese participants exposed to Chinese symbols, and the reverse for European participants, therefore supporting the idea that conscious awareness is strongly influenced by domain-specific expertise.

In **Study 7a.4**, we focused on motor awareness by using Seibel (1963)’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 replicated, 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 performed perform 30 blocks (1023 trials; one each day for *30 days*) of the 1023-choice RT task. Five blocks (#1, 2, 4, 10, 30) were performed in the fMRI scanner. Further, on 10% of the trials, participants were prompted to reproduce the response they had just produced, so as to probe action awareness. We expected action awareness to show a non-monotic relationship to performance, as predicted. All the relevant data have been collected and are now being analysed. The behavioural results are in line with what we had predicted.

**WP7b** was aimed at exploring the effects of manipulating metarepresentations of one's own performance in different tasks. It is based on the hypothesis that the central difference between conscious and unconscious representations depends on the involvement of metarepresentations ("knowing that one knows", as per Higher-Order Thought theories of consciousness). One way in which metarepresentations can be manipulating consists of using hypnosis, placebo, or suggestion. In this respect, we have now completed a large study (**Study 7b.4)** comparing all three procedures in the context of the very same task (the Stroop task). Results indicate that all three procedures exert the same effects on performance, which lends support to Kirsh's expectancy theory. An article describing this research is under preparation.

We have also completed **Study 7b.6**, which aimed at documenting the effects of varying instructions (high-level vs. low-level) on task performance and conscious awareness. To do so, we manipulated level of processing while keeping the stimuli identical. Participants performed a discrimination task on coloured numbers and either judged the magnitude of the numbers or their hue. We hypothesized that stimulus duration would interact with the task (simple vs. complex) and exhibit a graded transition from unconscious to conscious processing in the hue condition and a non-linear transition in the numerical condition. This is indeed what we found. The study has now been published (Windey et al., 2013), together with further reports (Windey et al., 2014) focused on the same design.

Finally, concerning **WP7c**, which is dedicated to the idea that consciousness depends on learning, we are now actively planning further collaboration with **INT1** and **INT2** to leverage a robotic hand that we have developed at ULB and that will make it possible to explore the effects of neurofeedback and of hypnosis on the sense of agency. Two studies have been published already in this line of research (Caspar et al., 2014, 2015).

## WP8 — Mechanisms of cultural learning

**Lead Partner: P1b** (ULB – Kolinsky & Content)
**Associated teams: P4** (UCL – Rossion) & **P2a** (UG — De Houwer)

**WP8a: Neural recycling and neural competition.** Learning to read requires the acquisition of an efficient visual procedure for quickly recognizing fine print and could therefore induce perceptual learning effects at early stages of the visual system. By using functional magnetic resonance imaging (fMRI) in literate and illiterate adults, we previously demonstrated an impact of reading acquisition on both high- and low-level occipito-temporal visual areas (Dehaene et al., *Science*, 2010), but could not resolve the time course of these responses. In our new study (Pegado et al., in press), we aimed at clarifying whether literacy impacts on early vs. late stages of visual processing by measuring event-related potentials to various categories of visual stimuli in adults with variable levels of literacy, including illiterates, early-schooled literates, and participants who learned to read in adulthood. To evaluate the precision with which the stimuli were encoded, we studied repetition effects by presenting the stimuli in pairs comprising repeated, mirrored or unrelated pictures from the same category. The results indicated that reading ability correlated with a broad enhancement of early visual processing (~100-150 ms) in the left occipito-temporal region, including increased repetition suppression, suggesting better exemplar discrimination, and increased mirror discrimination. These effects were found with letter strings and false fonts, but also partly generalized to other, nonlinguistic visual categories, particularly faces. Thus, learning to read affects the magnitude, the precision, and the invariance of early visual processing. As regards mirror invariance, a behavioural study on the same type of participants (Kolinsky & Fernandes, 2014) showed in addition that the increased mirror discrimination capacity interferes with object identity processing in literate (but not illiterate) adults, which is a negative side effect of reading acquisition. In addition, as neural competition with face processing had also been observed in our fMRI study, we have run a new set of experiments on illiterate adults to investigate the behavioral consequences of this effect; these data are under analysis.

In a parallel project, we have been working on the development of robust implicit measures of reading using electroencephalography (EEG) during fast periodic visual stimulation. In a first study, sequences of pseudofonts, nonwords, or pseudowords were presented through sinusoidal contrast modulation at a periodic 10 Hz frequency rate (F), in which words were interspersed at regular intervals of every fifth item (i.e., F/5, 2 Hz). Participants had no linguistic task to perform. Within only 3 minutes of stimulation, a robust discrimination response for words at 2 Hz (and its harmonics) was observed in all conditions, located predominantly over the left occipito-temporal cortex. The magnitude of the response was largest for words embedded in pseudofonts, and larger in nonwords than in pseudowords, showing that list context effects classically reported in behavioral lexical decision tasks are due to visual discrimination rather than decisional processes. Remarkably, the oddball response was significant even for the critical words/pseudowords discrimination condition in every individual participant. These results have been recently published (Lochy et al., 2015) and highlight the potential of an EEG fast periodic visual stimulation approach for understanding the representation of written language. We are currently implementing this approach to measure the development of specialized functional responses to alphabetic characters vs. to faces in children (Lochy, Van Reybroeck, Rossion, in prep). 42 children of 5 years old (pre-readers) were tested with the above-described paradigm in order to assess their brain discrimination responses to words or pseudowords among pseudo-font characters, as well as words among pseudowords. In parallel their discrimination responses to face identities were also recorded. Preliminary results show first, a left-dominant discrimination response to alphabetic characters among pseudo-font (and as expected, no discrimination of words among pseudowords) and second, a right-dominant response to faces. After a few months of learning correspondences between graphemes and phonemes, the response to faces decreased slightly in the left hemisphere and was stable in the right hemisphere. Although these results are preliminary, they encourage us to pursue this line of research with a follow-up study after one year of formal schooling, in order to test precisely the hypothesis of an impact of learning to read of the brain lateralization of face processing.

**WP8b: Does learning new cultural categories modify natural categories?** Previous work demonstrated that literacy affects speech processing. In particular, our comparative fRMI data on illiterate and literate adults (Dehaene et al., *Science* 2010) showed that spoken inputs activate brain regions involved in phonological processing (e.g., the planum temporale) to a greater extent in literate than illiterate adults. As discussed by Kolinsky (in press) and by Kolinsky, Morais, Cohen, Dehaene-Lambertz, & Dehaene (2014), this raises 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. To study this question, we plan to examine speech identification and discrimination of spoken strings. To this aim, with collaboration with Prof. Willy Serniclaes (Speech perception group, Univ. Paris 5), we designed a new material to test speech identification and discrimination of speech continua varying in either place of articulation or voicing. Thanks to our international collaborations this material (created by morphing natural endpoint syllables) will be applied soon on illiterate adults. In addition, we examined whether literacy may also modify semantic categories (Kolinsky et al., 2014). In two experiments, adults of varying levels of formal education were presented with semantic fluency tests. Fluency was analyzed in terms of overall performance, sequential order and speed of responses. Despite lower performance, illiterates and adults with null or limited formal education displayed taxonomic clustering and retrieval by semantic subcategory, as did participants with higher formal education levels. This shows that formal education and literacy impact the richness and precision of semantic knowledge but not the organization of semantic categories and basic mechanisms of access to them. Yet, formal education and literacy slightly speed up access to categories, probably by providing useful (e.g., phono-graphemic) cues for generating category exemplars.

**WP8c: Explicit and implicit aspects of orthographic learning.** Aside its cerebral consequences, learning a script entails functional effects that influence behavioral performance. Efficient readers process letters in parallel and are capable of organizing letter strings into multiletter chunks. We have proposed that readers categorize letters into consonants and vowels (irrespective of their contextual phonological rendering), and that the CV pattern, i.e., the organization of consonants and vowels in the string, constitutes the major determinant of parsing and chunking. We have extended the previous evidence obtained through the syllable counting task and the length estimation task (see previous report, Chetail & Content, 2014) in two ways: 1) by examining the influence of the CV pattern in other languages than French, and 2) by examining performance in the perceptual matching task.

1) Studies run in Italian (Chetail, Scaltritti & Content, 2014) and in English, in collaboration with colleagues from Washington University (Chetail, Balota, Treiman & Content, 2014) produces convergent evidence to demonstrate the influence of the CV pattern on perceptual structure.

2) In the perceptual matching task, participants see two successive letter strings and are asked to decide, as quickly as possible, whether the two strings comprise exactly the same letters or not. In the mismatching trials, the targets were pseudowords built by the transposition of 2 adjacent letters from base strings. In one condition, the pseudowords had the same number of vowel clusters as the base word, whereas in another condition, the transposition modified the number of vowel clusters (e.g., *poirver*: 2 vowel clusters vs. *povirer*: 3 vowel clusters, from *POIVRER*: 2 vowel clusters). Six experiments were conducted and demonstrated that the orthographic representation of letter strings is influenced by the CV pattern at an early, prelexical processing stage (Chetail, Drabs & Content, 2014).

Further studies are in progress to provide direct information about the time course and cerebral localization of the extraction of structure through an MEG experiment, and to explore the development and acquisition of these mechanisms, through studies of perceptual processing in children during reading / spelling acquisition, and studies with adults exposed to novel, artificial scripts.

## WP9 — Project Management

**Lead Partner: P1a** (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 main objectives of this particular WP during the first year of the project were (1) to organize the kick-off meeting, and (2) to design and deploy the network's website. Both objectives were achieved.

# 5. NETWORK ORGANISATION AND OPERATION

Throughout its first two years of operation, that is, since October 2012, the network held three annual meetings as well as numerous smaller meetings involving only some its members. Overall it is fair to say that the network is now going strong, with several distinct collaborations already in place or in advanced planning stages. Thanks to these different initiatives and to the fact that the most of the junior members of the network have now been hired, the partners are beginning to know each other's work in depth and are now in a position to plan even further collaborative work. The network's website is proving to be an excellent repository and central hub for the network's activities.

In the following we provide a brief overview of the network's activity during its first two years.

The **website** associated to the network was launched on the occasion of the second annual meeting. The website can be found at the following URL: http://www.iap-cool.net. The website contains (1) announcements of network-relevant events, (2) a description of the overall goals of the project, broken down by Work Packages and listing associated personnel, (3) a listing of all personnel (PIs, post-docs, and Ph.D. students) associated to the project, and (4) an archive of all the documents associated with the project (i.e., scientific publications, presentations, meeting programs, minutes of administrative meetings, scientific reports). The website has been very well received and is used regularly by members of the network to keep it up-to-date.

During **2013**, the network held its first annual meeting (the kick-off meeting) on February 15th, 2013, at the Center for Research on Cognition & Neurosciences (ULB) in Brussels. The event was organized by **P1a** (Axel Cleeremans, ULB), the coordinator of the project. On the occasion of this day-long meeting, the different partners first introduced their team during the morning session, and offered an overview of the planned research in the afternoon. The meeting was attended by about 40 participants. The full program of the meeting, as well as most of the presentations that were delivered, are available on the network's website.

The second annual meeting (COOL2), organized by **P2a** (Jan De Houwer, UG) took place at "Het Pand" (Ghent) on November 5th, 2013. Again a day-long meeting, this featured progress updated from each of the workpackage leaders, a couple of focused presentations from junior partners, as well as a keynote presentation by Pr. David Shanks (University College London). The full program of the meeting, as well as most of the presentations that were delivered, are available on the network's website.

A third event dedicated to animal cognition, to which some of the partners (from ULB, KUL, and UG) were invited, was also co-organized in 2013 by **P2a** (Jan de Houwer, UG) and **P3** (Tom Beckers, KUL), again at "Het Pand" in Ghent.

In **2014**, four important network-related events took place. On February 6th, **P2a** (Jan de Houwer, UG) and **P2b** organized a meeting dedicated to "Learning via instructions". On September 26th, **P1a** (Axel Cleeremans, ULB) organized a special lecture titled "How experience leads to readiness to learn" at the University Fondation in Brussels for Pr. Jay L. McClelland on the occasion of his receiving the Heineken Prize for Cognitive Science. On October 13th, 2014, **P2a** (Jan de Houwer, UG) and **P3** (Tom Beckers, KUL) organized a one-day symposium dedicated to associative vs. propositional processes in learning at "Het Pand" in Ghent. Details about these events are all available on the network's website.

Finally, the third annual meeting (COOL3) was organized at the Irish College (KULeuven) by **P4** (Beckers, KUL) on December 11th, 2014. Featuring updates by the WP leaders in the morning, the day-long meeting was focused on the contributions of the junior partners of the network in the afternoon. The meeting closed by a keynote presentation by Professor Alfons Hamm from the University of Greifswald (Germany). The full program of the meeting, as well as the presentations of the day, are available on the network's website.

Further networking events during 2014 include (1) the invitation by ULB of Tom Beckers **(P3)** to deliver a series of lectures as invited professor on "conditioning", and (2) a seminar delivered by Isabelle Massat and Philppe Peigneux (**P1a)** at KULeuven.

In addition to these network-wide events, the teams involved in each workpackage also interacted on numerous occasions throughout the year, as follows:

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

**Lead Partner: P4** (UCL – Rossion)
**Associated teams: P1a** (ULB – Peigneux & Cleeremans)

**2013**

- Informal work meeting organized between ULB and UCL members participating to WP1, UCL, October 15th, 2013 (with P. Peigneux, L. Quenon, A. Lochy, B. Rossion). Planning of training experiments
- Setting up of a collaboration between Patrick Haggard (UCL, London) and Bruno Rossion. Meeting between Lisa Quenon, Goedele Van Belle, Bruno Rossion, and Guido Orgs (postdoctoral researcher P. Haggard) on an EEG study of biological motion perception. April 2013.

**2014**

- Collaboration between Patrick Haggard (UCL, London) and Bruno Rossion. Meeting between Lisa Quenon, Bruno Rossion, and Patrick Haggard for writing up the paper on an EEG study of biological motion perception. January 2014.

## WP2 — Mechanisms of conditioning and causal learning

**Lead Partner: P3** (KUL – Beckers)
**Associated teams: P2a** (UG – De Houwer), **P1** (ULB – P1a: Cleeremans & Peigneux, P1b: Kolinsky)

**2013**

- Informal work package meetings were organized between KU Leuven and Universiteit Gent partners (researchers involved: Beckers, De Houwer, Boddez, Maes, Beurms, Coppens) on September 26, 2012, on December 18, 2012, on January 15, 2013, on April 11, 2013, on May 21, 2013, and on November 19, 2013.
- Informal work package meetings were organized between KU Leuven and ULB partners (researchers involved: Beckers, Peigneux, Boddez, Gilson, Farthouat) on September 25, 2012, on October 29, 2012, and on November 6, 2013
- Tom Beckers (KU Leuven) is a member of the doctoral supervisory committees of Gaëtan Mertens (U Gent), Ama Kissi (U Gent) and Esti San Anton (ULB).
- Jan De Houwer (U Gent) is co-promotor of Elisa Maes (KU Leuven), Sarah Beurms (KU Leuven) and Perine Coppens (KU Leuven)
- At the invitation of Philippe Peigneux, Tom Beckers (KU Leuven) will be a visiting professor at ULB in 2013-2014, giving a series of research seminars to master students, doctoral students and staff.
- Tom Beckers (KU Leuven) and Jan De Houwer (U Gent) are jointly organizing an expert meeting on Animal Cognition in Gent, December 19-20. Among the attendants will be partners from KU Leuven, U Gent and ULB.

**2014**

- The third annual meeting of the IAP program was organized in Leuven on December 11, 2014.
- Informal work package meetings were organized between KU Leuven and Universiteit Gent partners (researchers involved: Beckers, De Houwer, Boddez, Maes, Beurms, Coppens) on February 7, April 4, and October 13, 2014.
- Informal work package meetings were organized between KU Leuven and ULB partners (researchers involved: Beckers, Peigneux, Boddez, Gilson, Farthouat, Slama, Deliens, Mary) on September 29th, November 6th, November 26th, December 10th, 2014.

- Philippe Peigneux (ULB) gave a seminar at KU Leuven, at the invitation of Tom Beckers, on February 4, 2014.
- Tom Beckers (KU Leuven) is a member of the doctoral supervisory committees of Gaëtan Mertens (U Gent), Ama Kissi (U Gent) and Esti San Anton (ULB).
- Jan De Houwer (U Gent) is co-promotor of Elisa Maes (KU Leuven), Sarah Beurms (KU Leuven) and Perine Coppens (KU Leuven)
- At the invitation of Philippe Peigneux, Tom Beckers (KU Leuven) was visiting professor at ULB in 2013-2014, giving a series of research seminars to master students, doctoral students and staff in spring 2014.
- Tom Beckers (KU Leuven) and Jan De Houwer (U Gent) are guest editing a special section of the *Journal of Comparative Psychology*, published by the American Psychological Association, on the topic of associative versus propositional accounts of animal learning, to be published in 2015.
- Tom Beckers (KU Leuven), Yannick Boddez (KU Leuven, postdoc on IAP grant) and Philippe Peigneux (ULB) successfully applied for an FWO grant to study the role of sleep in generalization. We will hire a PhD student on the grant in spring 2015 who will join the IAP team.
- Tom Beckers (KU Leuven), Yannick Boddez (KU Leuven) and Jan De Houwer (U Gent) are preparing a joint contribution for the Oxford Handbook of Causal Learning, edited by Michael Waldmann (to be published late 2015 / early 2016).

## WP3 — Mechanisms of Learning via instructions

**Lead Partner: P2a** (UG – De Houwer)
**Associated teams: P1a** (ULB – Cleeremans), **P2b** (UG – Brass) and **P3** (KUL – Beckers)

**2013**
- Marcel Brass is co-promotor of the PhD by Gaëtan Mertens (promotor: Jan De Houwer).
- Axel Cleeremans and Tom Beckers are members of the guidance committee of Gaëtan Mertens that met in on 19 February 2013.
- Jan De Houwer, Yannick Boddez, and Tom Beckers are preparing papers on propositional theories of learning.

**2014**
- Marcel Brass, Axel Cleeremans and Tom Beckers are members of the guidance committee of Gaëtan Mertens that met on 19 February 2013 and 3 October 2014
- Axel Cleeremans, Marijke Theeuwes, Baptist Liefooghe, and Jan De Houwer met in Ghent to discuss the possibility of using suggestion techniques to increase the effects of instructions on automatic response activation. A study along the lines discussed at the meeting will be conducted in May 2015.
- Yannick Boddez, Jan De Houwer, and Tom Beckers have written a chapter on propositional theories of learning that is soon to be submitted for publication.
- Jan De Houwer and Marcel Brass organized an IUAP meeting on learning via instructions on Thursday 6 February 2014.
- Jan De Houwer and Tom Beckers organized and IUAP meeting on association formation versus propositional theories of learning on 13 October 2014.

## WP4 — Mechanisms of implicit learning

**Lead Partner: INT2** (Sussex – Dienes)
**Associated teams: P1a** (ULB – Cleeremans) and **P3** (KUL — Beckers)

**2013**
- No formal networking this year beyond participation in the overall COOL meetings.

**2014**
- No formal networking this year beyond participation in the overall COOL meetings. By linking to **WP6** we hope to network more in 2015.

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

**Lead Partner: P2b** (UG – Brass)
**Associated teams: P1a** (ULB – Cleeremans & Peigneux) and **INT1** (UCL – Haggard)

**2013**

- Brussels: September 19th : Marcel Brass and Axel Cleeremans met in Brussels discussed some project ideas related to WP5
- London: September 26th: Marcel Brass met with Patrick Haggard to plan further collobaration.
- Ghent: November 5th, 2013: COOL2 meeting. Here Marcel Brass and Patrick Haggard discussed the possibility to carry out a line of joint experiments on decision making. Martijn Teuchies will visit **INT1** in London to further discuss the details of the experiments.
- Ghent/London: November 18th: Skype meeting with Marcel Brass, Patrick Haggard, Nura Sidarus and Martijn Teuchies to get an overview of the collaboration between Patrick Haggard and Marcel Brass.
- London: November 21th, 2013: Martijn Teuchies met with Patrick Haggard and Nura Sidarus to discuss the details of a series of joint experiments. A pilot study will take place in Ghent, followed by fMRI data collection carried out by Martijn Teuchies and Nura Sidarus.

**2014**

- Ghent; April 3 – 5 & June 5 - 7: Nura Sidarus and Martijn Teuchies have collected fMRI data for the first **WP5** experiment.
- **P2b** (Brass) is a member of the guidance committee of Emilie Caspar (**P1a** - Cleeremans)

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

**Lead partner: INT1** (UCL – Haggard)
**Associated teams: P1a** (ULB – Cleeremans) and **P2b** (UG – Brass)

**2013**

- "Intentional Inhibition", organisation of a first international expert workshop, London, 25/9/2013 (Oral contributions by Marcel Brass and Patrick Haggard).

**2014**

- Ghent; April 3 – 5 & June 5 - 7: Nura Sidarus and Martijn Teuchies have collected fMRI data for the first **WP5** experiment.
- Numerous weekly visits to **INT1** (Haggard – UCLondon) by Emilie Caspar (**P1a** - Cleeremans) in the context of the ongoing collaboration between the two teams.

## WP7 — Mechanisms of awareness: Learning to be conscious

**Lead Partner: P1a** (ULB – Cleeremans)
**Associated teams: P2b** (UG – Brass), **P4** (UCL – Rossion), **INT1** (UCLondon – Haggard) & **INT2** (USussex – Dienes)

**2013**

- A discussion involving Haggard, Dienes & Cleeremans took place on the 2nd COOL meeting about collaboration around the exploration of the sense of agency under hypnosis in a Libet-like situation involving the robotic hand available in Brussels.

**2014**

- Numerous weekly visits to **INT1** (Haggard – UCLondon) by Emilie Caspar (**P1a** - Cleeremans) in the context of the ongoing collaboration between the two teams.
- Continued discussion of the planned studies on agency, agency, and hypnosis with **INT1** and **INT2**.

- Proposed co-supervision of a Ph.D. Thesis by **P2b** (Brass) and **P1a** (Cleeremans)
- **P1a** (Cleeremans) is a member of the guidance committee of Martijn Teuchies (**P2b** - Brass)

## WP8 — Mechanisms of cultural learning

**Lead Partner: P1b** (ULB – Kolinsky & Content)
**Associated teams: P4** (UCL – Rossion) & **P2a** (UG — De Houwer)

**2013**

- **P1b** (Kolinsky, ULB) organized an informal work meeting focused on the interactions with **P5** (Rossion, UCL) on June 19, 2013. The program involved presentations by Régine Kolinsky, Bruno Rossion & Aliette Lochy, and Alain Content and continued in the afternoon with discussions of the work plan.

**2014**

- No formal networking this year beyond participation in the overall COOL meetings.

# 6. PUBLICATIONS

## 6.1 PUBLICATIONS PRESENTED BY TEAMS

As requested, we list here the publications that specifically acknowledge the support of the IAP Program, listed separately for each team associated to the project. All publications are available either directly on www.iap-cool.net or on open-access institutional repositories.

### P1a & P1b: ULB — Center for Research in Cognition & Neurosciences

**Principal Investigators: A. Cleeremans, A. Content, R. Kolinsky, P. Peigneux**


Atas, A., Vermeiren, A., & Cleeremans, A. (2013). Repeating a strongly masked stimulus increases priming and awareness. *Consciousness and Cognition, 22*, 1422-1430.

Atas, A., Faivre, N., Timmermans, B., Cleeremans, A., & Kouider, S. (2014). Nonconscious Learning From Crowded Sequences. *Psychological Science*, *25*(1), 113–119.

Atas, A., San Anton, E., & Cleeremans, A. (2014, September 26). The reversal of perceptual and motor compatibility effects differs qualitatively between metacontrast and random-line masks. Psychological research, 1-16. doi:10.1007/s00426-014-0611-3

Atas, A., & Cleeremans, A. (2015). The temporal dynamic of automatic inhibition of irrelevant actions. *Journal of Experimental Psychology: Human Perception and Performance*.

Caspar, E., De Beir, A., Magalhães de Saladanha da Gama, P., Yernaux, F., **Cleeremans, A.**, Vanderborght, B. (2014). New frontiers in the rubber hand experiment: When a robotic hand becomes one's own. *Behaviour Research Methods.* DOI: 10.3758/s13428-014-0498-3.

Caspar, E., Cleeremans, A., & Haggard, P. (2015). The relationship between human agency and embodiment. *Consciousness & Cognition, 33*, 226-236. DOI: 10.1016/j.concog.2015.01.007.

Chetail, F., & Content, A. (2013). What Is the Difference Between OASIS and OPERA? Roughly Five Pixels: Orthographic Structure Biases the Perceived Length of Letter Strings. *Psychological Science*, doi:10.1177/0956797613500508

Chetail, F., Balota, D., Treiman, R., & Content, A. (2014). What can megastudies tell us about the orthographic structure of English words? *The Quarterly Journal of Experimental Psychology*, Published online: 07 Nov 2014, doi:10.1080/17470218.2014.963628

Chetail, F., & Content, A. (2014). What Is the Difference Between OASIS and OPERA? Roughly Five Pixels: Orthographic Structure Biases the Perceived Length of Letter Strings. *Psychological Science*, *25*(1), 243–249. doi:10.1177/0956797613500508

Chetail, F., Drabs, V., & Content, A. (2014). The role of consonant/vowel organization in perceptual discrimination. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *40*(4), 938–961. doi:10.1037/a0036166

Chetail, F., Scaltritti, M., & Content, A. (2014). Effect of the consonant-vowel structure of written words in Italian. *The Quarterly Journal of Experimental Psychology: Section A*, 67 (5), 833-842, DOI: 10.1080/17470218.2014.898668.

Cleeremans, A. (2014). Connecting conscious and unconscious cognition. *Cognitive Science.* DOI: 10.1111/cogs.12149.

Doyen, S., Klein, O., Simons, D., & Cleeremans, A. (2014). On the other side of the mirror: Priming in cognitive and social psychology. *Social Cognition*, 32 (Supplement: Understanding priming effects in social psychology), 12-32. DOI: 10.1521/soco.2014.32.supp.12.

Kolinsky, R. (in press). How learning to read influences language and cognition. In A. Pollatsek & R. Treiman (Eds.), *The Oxford Handbook of Reading*. New York: Oxford University Press. doi: 10.1093/oxfordhb/9780199324576.013.29. Available on–line at www.oxfordhandbooks.com

Kolinsky, R., & Fernandes, T. (2014). A cultural side effect: Learning to read interferes with object identity processing. *Frontiers in Psychology*. doi: 10.3389/fpsyg.2014.01224

Kolinsky, R., Monteiro-Plantin, R. S., Mengarda, E. J., Grimm-Cabral, L., Scliar-Cabral, L., & Morais, J. (2014). How formal education and literacy impact on the content and structure of semantic categories.

*Trends in Neuroscience and Education, 3*, 106-121. doi: 10.1016/j.tine.2014.08.001
Kolinsky, R., Morais, J., Cohen, L., Dehaene-Lambertz, G. & Dehaene, S. (2014). L'influence de l'apprentissage du langage écrit sur les aires du langage/The impact of literacy on the language brain areas. *Revue de Neuropsychologie, 6*, 173-181.
Pegado, F., Comerlato, E., Ventura, F., Jobert, A., Nakamura, K., Buiatti, M., Ventura, P., Dehaene-Lambertz, G., Kolinsky, R., Morais, J., Braga, L. W., Cohen, L., & Dehaene, S. (2014, in press). *Timing the impact of literacy on visual processing*. Proceedings of the National Academy of Sciences of the United States of America. (SCI IF 9.737). doi: 10.1073/pnas.1417347111
Ventura, P., Fernandes, T., Cohen, L., Morais, J., Kolinsky, R., & Dehaene, S. (2013). Literacy acquisition reduces the automatic holistic processing of faces and houses. *Neuroscience Letters, 554*, 105-109.
Windey, B., Gevers, W., & Cleeremans, A. (2013). Subjective visibility depends on level of processing. *Cognition, 44*(2), 404-409.
Windey, B., Vermeiren, A., Atas, A., & Cleeremans, A. (2014). The graded and dichotomous nature of visual awareness. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 369 (1641). DOI:10.1098/rstb.2013.0282.

## P2a: UG — Learning and Implicit Processes Laboratory

**Principal Investigator: J. De Houwer**

Raes, A. K., De Houwer, J., De Schryver, M., Brass, M., & Kalisch, R. (in press). Do CS-US pairings actually matter? A within-subject comparison of instructed fear conditioning with and without actual CS-US pairings. PLoS ONE.

## P2b: Universiteit Gent — Department of Experimental Psychology

**Principal Investigator: M. Brass**

Bardi, L., Bundt, C., Notebaert, W. & Brass, M. (in revision). Eliminating mirror responses via instructions. Cortex.

## P3: KUL — Center for the Psychology of Learning and Experimental Psychopathology

**Principal Investigator: T. Beckers**

Boddez, Y., Haesen, K., Baeyens, F., & Beckers, T. (2014). Selectivity in associative learning: A cognitive stage framework for blocking and cue competition phenomena. *Frontiers in Psychology, 5,* doi:10.3389/fpsyg.2014.01305.
Luyten, L., Boddez, Y., & Hermans, D. (2015). Positive appraisal style: The mental immune system? *Behavioral and Brain Sciences*, in press.
Van Lier, J., Vervliet, B., Boddez, Y., & Raes, F. (2014). "Why is everyone always angry with me?!": When thinking 'why' leads to generalization. *Journal of Behavior Therapy and Experimental Psychiatry*, in press.

## P4: UCL — Face Categorization Laboratory

**Principal Investigator: B. Rossion**

Bukowski, H., Dricot, L., Hanseeuw, B., & Rossion, B. (2013). Cerebral lateralization of face-sensitive areas in left-handers: only the FFA does not get in right. *Cortex*, 49, 2853-2859. Available at: http://face-categorization-lab.webnode.com/publications/
Busigny, T., Van Belle, G., Jemel, B., Hosein, A., Joubert, S., Rossion, B. (2014). Face-specific impairment in holistic perception following focal lesion of the right anterior temporal lobe. *Neuropsychologia*, 56, 312-333.

Caharel, S., Ramon, M., Rossion, B. (2014). Face familiarity decisions take 200ms in the human brain: electrophysiological evidence. *Journal of Cognitive Neuroscience,* 26, 81-95.

Dormal, G., Lepore, F., Harissi-Dagher, M., Albouy, G., Bertone, A., Rossion, B., Collignon, O. (in press). Tracking the evolution of crossmodal plasticity and visual functions before and after sight-restoration. *Journal of Neurophysiology*.

Lochy, A., Van Belle; G., Rossion, B. (2015). A robust index of lexical representation in the left occipito-temporal cortex as evidenced by EEG responses to fast periodic visual stimulation. *Neuropsychologia*, 66, 18-31.

Van Belle, G., Lefevre, P., & Rossion, B. (2015). Face inversion and acquired prosopagnosia reduce the size of the perceptual field of view. *Cognition, 136*, 403-408.

## INT1: University College London — Institute of Cognitive Neuroscience

**Principal Investigator: P. Haggard**

Chambon, V., Filevich, E., & Haggard, P. (2014). What is the Human Sense of Agency, and is it Metacognitive? In S. M. Fleming & C. D. Frith (Eds.), The Cognitive Neuroscience of Metacognition (pp. 321–342). Springer Berlin Heidelberg.

Chambon, V., Sidarus, N., & Haggard, P. (2014). From action intentions to action effects: how does the sense of agency come about? Frontiers in Human Neuroscience, 8, 320. doi:10.3389/fnhum.2014.00320

Stenner, M.-P., Bauer, M., Sidarus, N., Heinze, H.-J., Haggard, P. & Dolan, R. (2014) Subliminal action priming modulates the perceived intensity of sensory action consequences. Cognition. 130 (2), 227-235.

Sidarus, N., Chambon, V., & Haggard, P. (2013). Priming of actions increases sense of control over unexpected outcomes. Consciousness and Cognition, 22 (4), 1403–1411. doi:10.1016/j.concog.2013.09.008

Filevich, E., Vanneste, P., Brass, M., Fias, W., Haggard, P. & Kuhn, S. (2013). Brain correlates of subjective freedom of choice. Consciousness and Cognition, 22, 1271-1284.

Kuhn, S., Brass, M. & Haggard, P. (2013). Feeling in control: neural correlates of experience of agency. Cortex, 49, 1935-1942.

## INT1: Sussex University — School of Psychology

**Principal Investigator: Z. Dienes**

Li, F., Jiang, S., Guo, X., Yang, Z., & Dienes, Z. (2013). The nature of the memory buffer in implicit learning: Learning Chinese tonal symmetries. *Consciousness & Cognition, 22* (3), 920-930.

Dienes, Z., Lush, P., Semmens-Wheeler, R., Parkinson, J., Scott, R. B., & Naish, P. (in press). Hypnosis as self-deception; Meditation as self-insight. In A. Raz and M. Lifshitz (Eds), *Hypnosis and Meditation: Toward an integrative science of conscious planes*. Oxford University Press

## 6.2 JOINT PUBLICATIONS

Below appear publications that involve several teams associated with the network:

Filevich, E., Vanneste, P., Brass, M., Fias, W., Haggard, P. & Kuhn, S. (2013). Brain correlates of subjective freedom of choice. *Consciousness and Cognition, 22*, 1271-1284. (**UG & UCLondon**)

Kuhn, S., Brass, M. & Haggard, P. (2013). Feeling in control: neural correlates of experience of agency. *Cortex, 49,* 1935-1942. (**UG & UCLondon)**

Raes, A. K., De Houwer, J., De Schryver, M., Brass, M., & Kalisch, R. (2014). Do CS-US pairings actually matter? A within-subject comparison of instructed fear conditioning with and without actual CS-US pairings. PLoS ONE 9(1): e84888. doi:10.1371/journal.pone.0084888 (**UG: P2a & P2b)**.

Caspar, E., Cleeremans, A., & Haggard, P. (2015). The relationship between human agency and embodiment. Consciousness and cognition, 33, 226-236. (**ULB & UCLondon**).