CHAPTER II

REVIEW OF LITERATURE

A review of research report related to the present study that the researcher scholar could gather, is presented in this chapter, in order to provide the background material to evaluate the significance of this study as well as to interpret its findings.

Jordan A. Taylor et al. (2014)⁴⁴, has conducted a study on explicit and implicit contributions to learning in a sensorimotor adaptation task, visuomotor adaptation has been thought to be an implicit process that results when a sensory-prediction error signal is used to update a forward model. Striking feature of human competence is the ability to receive verbal instructions and employ strategies to solve tasks; such explicit processes could be used during visuomotor adaptation. Here, we used a novel task design that allowed us to obtain continuous verbal reports of aiming direction while participants learned a visuomotor rotation. We had two main hypotheses: the contribution of explicit learning would be modulated by instruction and the contribution of implicit learning would be modulated by the form of error feedback. By directly assaying aiming direction, we could identify the time course of the explicit component and, via subtraction, isolate the implicit component of learning. There were marked differences in the time courses of explicit and implicit contributions to learning. Explicit learning, driven by target error, was achieved by initially large then smaller explorations of aiming direction biased toward the correct solution. In contrast, implicit learning, driven by a sensory-prediction error, was slow and monotonic. Continuous error feedback reduced the amplitude of explicit learning and increased the contribution of implicit learning. The presence of instruction slightly increased the rate of initial learning and only had a subtle effect on implicit learning. We conclude that visuomotor adaptation, even in the absence of instruction, results from the interplay between explicit learning driven by target error and implicit learning of a forward model driven by prediction error.

Michiel P. L. D. et al. (2014)\textsuperscript{45}, It has been proposed that effects of aging are more pronounced for explicit than for implicit motor learning. The authors evaluated this claim by comparing the efficacy of explicit and implicit learning of a movement sequence in young and older adults, and by testing the resilience against fatigue and secondary tasking after learning. It was also examined whether explicit learning in older adults can be promoted by alleviating time constraints during learning. Methods: The alternating serial reaction time task (ASRTT) was used. Experiment 1 compared the benefits of receiving full instructions about the stimulus sequence relative to receiving no instructions in young (20-25 years) and older (50-65 years) adults during retention and during transfer to fatigue and secondary task conditions. Experiment 2 alleviated time constraints during the initial bouts of practice with full instructions. Results: Experiment 1 indicated that the older adults learned on the ASRTT and achieved similar performance as young adults when no instructions were given. In contrast to the young adults, learning was not superior in older adults who received full instructions compared with those who did not. Experiment 2 indicated that alleviating time constraints allowed some of the older adults to gain from instruction but only under relatively low time constraints, but there was no retention with rigorous time constraints. Conclusion: Explicit learning, but not implicit learning, declines in older adults. This is partly due to older adults difficulties to apply explicit knowledge. Less rigorous time constraints can help to ameliorate some of these difficulties and may induce levels of explicit learning in older adults that will result in superior performance compared with implicit learning. Implicit learning did occur under time constraints that prevented explicit learning.

Melanie Kleynen et al. (2014)\textsuperscript{46} has evaluated a Delphi technique to seek consensus regarding definitions, descriptions and classification of terms related to implicit and explicit forms of motor learning. Background: motor learning is central to domains such as sports and rehabilitation; however, often terminologies are insufficiently uniform to allow effective sharing of experience or translation of knowledge. A study


using a Delphi technique was conducted to ascertain level of agreement between experts from different motor learning domains (i.e., therapists, coaches, researchers) with respect to definitions and descriptions of a fundamental conceptual distinction within motor learning, namely implicit and explicit motor learning. Methods: A Delphi technique was embedded in multiple rounds of a survey designed to collect and aggregate informed opinions of 49 international respondents with expertise related to motor learning. The survey was administered via an online survey program and accompanied by feedback after each round. Consensus was considered to be reached if 70% of the experts agreed on a topic. Results: Consensus was reached with respect to definitions of implicit and explicit motor learning, and seven common primary intervention strategies were identified in the context of implicit and explicit motor learning. Consensus was not reached with respect to whether the strategies promote implicit or explicit forms of learning. Discussion: The definitions and descriptions agreed upon may aid translation and transfer of knowledge between domains in the field of motor learning. Empirical and clinical research is required to confirm the accuracy of the definitions and to explore the feasibility of the strategies that were identified in research, everyday practice and education.

Natacha Deroost et al. (2014) has conducted a research on implicit and explicit learning of sequential motor skill in multiple sclerosis: directions for rehabilitation. Background and objectives: learning and memory impairment is one of the most persistent cognitive symptoms in multiple sclerosis (MS). In order to fine-tune rehabilitation interventions, a thorough understanding of the specific involvement of implicit and explicit learning processes underlying this impairment is required. To this aim, we determined sequential motor skill acquired under implicit and explicit instructions in MS. Methods: Sequential motor skill was determined using the serial reaction time task. In a randomized controlled trial, we assessed implicit and explicit sequence learning in twenty nine MS patients and twenty-seven matched controls. The primary outcome measure was the difference in RTs between reversed and repeated

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sequence blocks, indexing sequence learning. Result: Patients displayed less sequence learning than controls. This effect seemed more apparent in the explicit sequence learning condition, relative to the implicit sequence learning condition. Preliminary evidence suggests that explicit learning impairment was most obvious in patients with progressive MS.

Arnaud Witt et al. (2013)\(^4\), looked at how explicit and implicit test instructions in an implicit learning task affect performance. Typically developing children aged 5 to 8 years were exposed to artificial grammar learning. Following an implicit exposure phase, half of the participants received neutral instructions at test while the other half received instructions making a direct, explicit reference to the training phase. We first aimed to assess whether implicit learning operated in the two test conditions. We then evaluated the differential impact of age on learning performances as a function of test instructions. The results showed that performance did not vary as a function of age in the implicit instructions condition, while age effects emerged when explicit instructions were employed at test. However, performance was affected differently by age and the instructions given at test, depending on whether the implicit learning of short or long units was assessed.

Guillaume Chauvel et al. (2013)\(^5\), has evaluated the novice motor performance and presumed positive influence and whether it originates from declarative or from procedural knowledge using the explicit/implicit motor learning paradigm. To this end, 80 non golfers learned to perform a golf-putting task with high error rates (i.e., explicit motor learning), and thus relied on declarative knowledge, or low error rates (i.e., implicit motor learning), and thus relied on procedural knowledge. Afterward, they either put their memories of the previous motor experience into words or completed an irrelevant verbal task. Finally, they performed the putting task again. Verbalization did not improve novice motor performance: Putting was impaired, overall, and especially so for high-error


learners. It was conclude that declarative knowledge is altered by verbalization, whereas procedural knowledge is not.

Peyman Rajabi et al. (2013)\textsuperscript{50}, investigated the underlying effect of explicit and implicit strategy training on reading comprehension performance of Iranian high school students. To achieve the research objectives, the researchers selected a sample of 71 second grade high school students out of a population of 110 students. They were assigned into experimental and control groups randomly. The experimental group received explicit instruction of compensation strategy training in reading comprehension classes while the control group focused on implicit instruction of the same strategy. The outcomes of the post test were analyzed by SPSS which showed that the experimental group exposed to explicit compensation strategy training outperformed the control group which received implicit instruction.

Daniel J. Sanchez et al. (2013)\textsuperscript{51}, devised an experiment looking at explicit pre-training instruction does not improve implicit perceptual-motor sequence learning, memory systems theory argues for separate neural systems supporting implicit and explicit memory in the human brain. Neuropsychological studies support this dissociation, but empirical studies of cognitively healthy participants generally observe that both kinds of memory are acquired to at least some extent, even in implicit learning tasks. A key question is whether this observation reflects parallel intact memory systems or an integrated representation of memory in healthy participants. Learning of complex tasks in which both explicit instruction and practice is used depends on both kinds of memory, and how these systems interact will be an important component of the learning process. Theories that posit an integrated, or single, memory system for both types of memory predict that explicit instruction should contribute directly to strengthening task knowledge. In contrast, if the two types of memory are independent and acquired in parallel, explicit knowledge should have no direct impact and may serve in a


"scaffolding" role in complex learning. Using an implicit perceptual-motor sequence learning task, the effect of explicit pre-training instruction on skill learning and performance was assessed. Explicit pre-training instruction led to robust explicit knowledge, but sequence learning did not benefit from the contribution of pre-training sequence memorization. The lack of an instruction benefit suggests that during skill learning, implicit and explicit memory operate independently. While healthy participants will generally accrue parallel implicit and explicit knowledge in complex tasks, these types of information appear to be separately represented in the human brain consistent with multiple memory systems theory.

Alfieri, Louis et al. (2011)\textsuperscript{2}, has examined Does Discovery-Based Instruction Enhance Learning? In which discovery learning approaches to education have recently come under scrutiny (Tobias & Duffy, 2009), with many studies indicating limitations to discovery learning practices. Therefore, 2 meta-analyses were conducted using a sample of 164 studies: The 1st examined the effects of unassisted discovery learning versus explicit instruction, and the 2nd examined the effects of enhanced and/or assisted discovery versus other types of instruction (e.g., explicit, unassisted discovery). Random effects analyses of 580 comparisons revealed that outcomes were favourable for explicit instruction when compared with unassisted discovery under most conditions ($d = -0.38$, 95\% CI $[-.44, -.31]$). In contrast, analyses of 360 comparisons revealed that outcomes were favorable for enhanced discovery when compared with other forms of instruction ($d = 0.30$, 95\% CI $[.23, .36]$). The findings suggest that unassisted discovery does not benefit learners, whereas feedback, worked examples, scaffolding, and elicited explanations do. (PsycINFO Database Record (c) 2012 APA, all rights reserved)

F.F. Zhu et al. (2011)\textsuperscript{2}, conducted a study on neural co-activation as a yardstick of implicit motor learning and the propensity for conscious control of movement, two studies examined EEG co-activation (coherence) between the verbal-analytical (T3) and motor planning (Fz) regions during a golf putting task. In Study 1,


participants with a strong propensity to consciously monitor and control their movements, determined psychometrically by high scores on a movement specific Reinvestment Scale, displayed more alpha2 T3–Fz co-activation than participants with a weak propensity. In Study 2, participants who practiced a golf putting task implicitly (via an errorless learning protocol) displayed less alpha2 T3–Fz co-activation than those who practiced explicitly (by errorful learning). In addition, explicit but not implicit motor learners displayed more T3–Fz co-activation during golf putting under pressure, implying that verbal-analytical processing of putting movements increased under pressure. These findings provide neuropsychological evidence that supports claims that implicit motor learning can be used to limit movement specific reinvestment.

Gu Xiao-le (2011)54, has conducted the study to find out whether explicit and implicit instructions of request strategies will be effective in helping Chinese EFL learners gain pragmatic knowledge and achieve pragmatic appropriateness in on-line communication. Participants in this study are randomly distributed into an explicit group and an implicit group. Request strategies and formulae were taught to the two groups in different ways. The explicit group underwent five phases, including request authentic exposure phase, strategy identification phase, Meta pragmatic information transmission phase, Meta pragmatic judgment phase, and production practice phase. The implicit group was exposed to the same authentic input as the explicit group, but they experienced meaning-focused tasks before they entered production practice phase. A pre-test and a post-test, each of which consisted of a written discourse completion task (WDCT) and a role play, were given right before and after the intervention. The results showed that both groups demonstrated improvements in the WDCT after the intervention, but to different degree. The explicit group showed greater progress in the appropriate level of formality, directness, and politeness realized through the syntactic patterns, internal and external modifications, and sequence of request components. This suggests the necessity of incorporating consciousness-raising activities in the classroom instruction of pragmatics. However, learners of both groups showed little progress in oral role plays, which

indicates that more practice opportunities should be provided through which learners can gain familiarity and control over the target forms and form-function mapping.

Scott Barry Kaufman et al. (2010)\textsuperscript{55}, has examined the Implicit learning as ability, the ability to automatically and implicitly detect complex and noisy regularities in the environment is a fundamental aspect of human cognition. Despite considerable interest in implicit processes, few researchers have conceptualized implicit learning as ability with meaningful individual differences. Instead, various researchers (e.g., Reber, 1993; Stanovich, 2009) have suggested that individual differences in implicit learning are minimal relative to individual differences in explicit learning. In the current study of English 16-17 year old students, we investigated the association of individual differences in implicit learning with a variety of cognitive and personality variables. Consistent with prior research and theorizing, implicit learning, as measured by a probabilistic sequence learning task, was more weakly related to psychometric intelligence than was explicit associative learning, and was unrelated to working memory. Structural equation modelling revealed that implicit learning was independently related to two components of psychometric intelligence: verbal analogical reasoning and processing speed. Implicit learning was also independently related to academic performance on two foreign language exams (French, German). Further, implicit learning was significantly associated with aspects of self-reported personality, including intuition, openness to experience, and impulsivity. It was concluded that the implications of implicit learning as ability for dual-process theories of cognition, intelligence, personality, skill learning, complex cognition, and language acquisition.

Savion-Lemieux, T. et al. (2010)\textsuperscript{56}, has conducted an experiment, for examined the effect of practice pattern on the learning, consolidation (retention), and transfer of visual motor sequences. On day 1, participants were randomly assigned to the massed, Alternating, or random condition. On day 2, all participants were tested for consolidation and transfer. Learning was assessed through changes in accuracy and response


synchronization. We found that massed practice led to enhanced sensorimotor integration and timing (as measured by response synchronization), whereas random practice led to better stimulus–response association (as measured by accuracy). On day 2, all groups showed consolidation for both measures, as well as transfer for accuracy but not response synchronization. Overall, this pattern of results provides limited support for the contextual interference hypothesis. Our findings are consistent with differential encoding of specific domains of motor performance. We propose that learning of the more explicit stimulus–response association is a fast processes those benefits from random practice because it requires the acquisition of this association in multiple contexts. Once the association is learned, it seems resistant to interference and transferrable to a novel sequence. In contrast, learning of the sensorimotor integration and timing is a slower process that benefits from blocked training because practice in a single context allows fine-tuning of the response. Given that all groups showed consolidation, we postulate that learning that occurs in the context of interference can show consolidation.

Adam D. Gorman et al (2009) has investigated the efficacy of explicit and implicit perceptual training approaches designed to improve the pattern perception capabilities of skilled basketball players, relative to control and placebo groups. The explicit and implicit groups completed 4 weeks of training using temporally occluded video footage while the placebo group used general visual stimuli. Results from a video-based test showed no significant differences between the four groups after the training intervention, despite large absolute gains by the two experimental groups. After a 14-day retention interval, improvements by the control group suggested that test familiarity may have influenced the retention test results. The transfer data showed that the laboratory-based training failed to elicit a significant change in on-court performance. The results, while not statistically significant, highlight a number of key considerations when attempting to develop perceptual-cognitive abilities in experienced athletes and provide direction for researchers and practitioners when designing similar training approaches.

Wing Kai Lam et al. (2009) investigated analogy learning and the performance of motor skills under pressure. The efficacy of analogical instruction, relative to explicit instruction, for the acquisition of a complex motor skill and subsequent performance under pressure was investigated using a modified (seated) basketball shooting task. Differences in attention resource allocation associated with analogy and explicit learning were also examined using probe reaction times (PRT). Access to task-relevant explicit (declarative) knowledge was assessed. The analogy and explicit learning groups performed equally well during learning and delayed retention tests. The explicit group experienced a drop in performance during a pressured transfer test, relative to their performance during a preceding retention test. However, the analogy group’s performance was unaffected by the pressure manipulation. Results from PRTs suggested that both groups allocated equal amounts of attention resources to the task throughout learning and test trials. Analogy learners had significantly less access to rules about the mechanics of their movements, relative to explicit learners. The results are interpreted in the context of Eysenck and Calvo’s (1992) processing efficiency theory and Masters’s (1992) theory of reinvestment.

Ron Sun et al. (2007) has explored the details of the interaction of different learning modes: implicit learning, explicit hypothesis testing learning, and implicit-to-explicit knowledge extraction. Contrary to the common tendency in the literature to study each type of learning in isolation, this paper highlights the interaction among them and various effects of the interaction on learning, including the synergy effect. This work advocates an integrated model of skill learning that takes into account both implicit and explicit learning processes; moreover, it also uniquely embodies a bottom-up (implicit-to-explicit) learning approach in addition to other types of learning. The paper shows that this model accounts for various effects in the human behavioural data from the psychological experiments with the process control task, in addition to accounting for other data in other psychological experiments (which has been reported elsewhere). The

paper shows that to account for these effects, implicit learning, bottom-up implicit-to-explicit extraction and explicit hypothesis testing learning are all needed.

Sunbin Song et al. (2007)\(^{60}\), has studied the effect of explicit knowledge on implicit learning using a modified version of the Alternating Serial Response Time (ASRT) task, a probabilistic sequence learning paradigm that yields continuous and relatively pure measures of implicit learning. Results revealed that implicit learning occurred to the same extent, whether or not subjects had explicit knowledge. Some evidence, however, indicated that explicit knowledge could interfere with the expression of implicit learning early in training. In addition, there were dissociations between learning measures, in that reaction time and accuracy were differentially affected by explicit knowledge. These findings indicate that implicit sequence learning occurs independently of explicit knowledge, and help to explain previous discrepant findings.

Vidoni, Eric D et al. (2007)\(^{61}\), conducted a research on Achieving Enlightenment: What Do We Know About the Implicit Learning System and Its Interaction with Explicit Knowledge? Two major memory and learning systems operate in the brain: one for facts and ideas (ie, the declarative or explicit system), one for habits and behaviours (ie, the procedural or implicit system). Broadly speaking these two memory systems can operate either in concert or entirely independently of one another during the performance and learning of skilled motor behaviours. This Special Issue article has two parts. In the first, we present a review of implicit motor skill learning that is largely centred on the interactions between declarative and procedural learning and memory. Because distinct neuro anatomical substrates support unique aspects of learning and memory and thus focal injury can cause impairments that are dependent on lesion location, we also broadly consider which brain regions mediate implicit and explicit learning and memory. In the second part of this article, the interactive nature of these two memory systems is illustrated by the presentation of new data that reveal that both learning implicitly and acquiring explicit knowledge through physical practice lead to


motor sequence learning. In our new data, we discovered that for healthy individual's use of the implicit versus explicit memory system differently affected variability of performance during acquisition practice; variability was higher early in practice for the implicit group and later in practice for the acquired explicit group. Despite the difference in performance variability, by retention both groups demonstrated comparable change in tracking accuracy and thus, motor sequence learning. Clinicians should be aware of the potential effects of implicit and explicit interactions when designing rehabilitation interventions, particularly when delivering explicit instructions before task practice, working with individuals with focal brain damage, and/or adjusting therapeutic parameters based on acquisition performance variable.

Michael Joseph Sylvester et al. (2007), investigated teaching the unknowable: does analogy lead to implicit skill acquisition in a dart-throwing task? This experiment was conducted to examine the hypothesis that learning by analogy will invoke characteristics of an implicit mode of learning. On Day 1, dart novices learned to throw darts as close as possible to the centre of a target under one of three scenarios: control (without instruction), implicit (while performing a distracting secondary task), and analogy (while imagining an analogous physical image). Each participant threw 6 blocks of 40 darts, receiving repeated instructions before each block. The next day (Day 2), participants were tested for retention and for transfer by the addition of a secondary distracting task. The results showed that significant learning took place in all groups over a period of six learning blocks on the first day. There was also significant response to retention and transfer testing on Day 2. Learning to throw darts without instruction was shown to be superior to learning under both of the other conditions — analogy and secondary task. The study demonstrated that dart throwing instruction using analogy was insufficient to induce the beneficial features of implicit learning. The chosen elastic analogy, in fact, led to a significant deterioration of performance when compared to controls during transfer on Day 2. Sex and skill differences are unlikely to have played a significant role in the main findings. The findings are discussed within the framework of current literature.

Lara A Boyd et al. (2006)\textsuperscript{63} were looking after the Explicit Information Interferes with Implicit Motor Learning of both Continuous and Discrete Movement Tasks after Stroke. A large portion of the rehabilitation experience after stroke relies on implicit learning. However, our understanding of how best to facilitate motor learning after stroke is limited by a paucity of research that has explored the interaction between explicit information and implicit learning across various task domains. Previously we reported that the delivery of explicit instructions disrupted implicit motor learning after stroke that involved the sensorimotor cortical areas or basal ganglia. The purpose of this study was to determine the robustness of these findings by determining whether they could be replicated with 2 motor tasks, one discrete and one continuous, employed by the same group of participants. Then individuals with stroke in the sensorimotor cortical areas (SMC), 10 with stroke in the basal ganglia (BG), and 10 age-matched healthy controls (HC) participated in this study. Each completed 3 days of practice of both a discrete implicit motor task (the serial reaction time task) and a continuous motor task (the continuous tracking task); all returned on a fourth day for retention tests. By random designation, participants were divided into either the explicit information (EI) or no explicit information (No-EI) groups. Consistent with previous results, we found that the response to explicit information after stroke was uniformly negative regardless of task or lesion location; both stroke groups demonstrated an interference effect of explicit information while the healthy control group did not. Strengthening these findings is the fact that the interference effect of explicit information was not task dependent. This point is particularly important for rehabilitation scientists as they instruct clients during various therapeutic tasks after stroke. Our data suggest that certain forms of explicit information delivered before task practice may not be as useful for learning as discovering the solution to the motor task with practice alone, and this is regardless of the type of task being learned.

Poolton, J. M. Et al. (2006), investigated the influence of analogy learning on decision-making in table tennis: Evidence from behavioural data. In sports it may be necessary for a performer to make a decision and execute a movement in close succession, or even concurrently. The manner in which a movement is controlled may impact on the degree to which the performer is able to combine decisions and movements effectively. Previous work has shown that if control of the movement has been acquired explicitly, with a high declarative knowledge content, dual-task conditions can be disruptive to performance of the movement. Previous work has also shown that, in contrast, if movement control is acquired by analogical instruction, with a low declarative knowledge content, motor performance is unaffected by dual-task conditions. It was, therefore, hypothesised that analogy learning will reduce the performance cost associated with processing motor responses while making high-complexity decisions. Participants learnt to hit a table tennis topspin forehand using either a single analogical instruction or a set of written instructions (explicit learning). Motor performance was assessed when decisions about the direction in which to hit the ball were either low in complexity or high in complexity. Low-complexity decisions had no effect on motor performance in either condition. However, high-complexity decisions caused relative performance deterioration in the explicit condition, but not in the Analogy condition. These findings extend the implicit motor learning literature by highlighting the role of analogy learning in the complex interaction between decision-making and movement control in sport.

Stefan Fischer et al. (2006), examined the question whether sleep can provide explicit knowledge on an implicitly acquired skill. At learning, young healthy subjects (n = 20) were first trained on the SRTT. Then, implicit knowledge was assessed on two test blocks, in which grammatically incorrect target positions were occasionally interspersed by the difference in reaction times between grammatically correct and incorrect target positions. To assess explicit sequence knowledge, thereafter subjects performed on a


generation task in which they were explicitly instructed to predict the sequential target positions. In half the subjects, learning took place before a 9-hour retention interval filled with nocturnal sleep (sleep group), in the other half, the retention interval covered a 9-hour period of daytime wakefulness (wake group). At subsequent retesting, both testing on the generation task and the SRTT test blocks was repeated. At learning before the retention interval, subjects displayed significant implicit sequence knowledge which was comparable for the sleep and wake groups. Moreover, both groups did not display any explicit sequence knowledge as indicated by a prediction performance not differing from chance on the generation task. However, at retesting, there was a distinct gain in explicit knowledge in the subjects who had slept in the retention interval, whereas generation task performance in the wake group remained at chance level. SRTT performance in the test blocks at retesting did not indicate any further gain in skill (i.e., unchanged reaction time differences between grammatically correct and incorrect target positions) independently of whether subjects had slept or remained awake after learning. Our results indicate a selective enhancement of explicit memory formation during sleep. Because before sleep subjects only had implicit knowledge on the sequence of target transitions, these data point to an interaction between implicit and explicit memory systems during sleep-dependent off-line learning.

Forkstam, Christian et al (2005)\textsuperscript{66}, looked towards an explicit account of implicit learning. Purpose of review: The human brain supports acquisition mechanisms that can extract structural regularities implicitly from experience without the induction of an explicit model. Reber defined the process by which an individual comes to respond appropriately to the statistical structure of the input ensemble as implicit learning. He argued that the capacity to generalize to new input is based on the acquisition of abstract representations that reflect underlying structural regularities in the acquisition input. We focus this review of the implicit learning literature on studies published during 2004 and 2005. We will not review studies of repetition priming (‘implicit memory’). Instead we focus on two commonly used experimental paradigms: the serial reaction time task and artificial grammar learning. Previous comprehensive reviews can be found in Seger's

1994 article and the Handbook of Implicit Learning. Recent findings: Emerging themes include the interaction between implicit and explicit processes, the role of the medial temporal lobe, developmental aspects of implicit learning, age-dependence, the role of sleep and consolidation.

**Arnaud Destrebecqz et al (2005)**

investigated the cerebral correlates of explicit and implicit knowledge in a serial reaction time (SRT) task. To do so, we used a novel application of the Process Dissociation Procedure, a behavioural paradigm that makes it possible to separately assess conscious and unconscious contributions to performance during a subsequent sequence generation task. To manipulate the extent to which the repeating sequential pattern was learned explicitly, we varied the pace of the choice reaction time task—a variable that is known to have differential effects on the extent to which sensitivity to sequence structure involves implicit or explicit knowledge. Results showed that activity in the striatum subtends the implicit component of performance during recollection of a learned sequence, whereas the anterior cingulated/medial prefrontal cortex (ACC/MPFC) supports the explicit component. Most importantly, we found that the ACC/MPFC exerts control on the activity of the striatum during retrieval of the sequence after explicit learning, whereas the activity of these regions is uncoupled when learning had been essentially implicit. These data suggest that implicit learning processes can be successfully controlled by conscious knowledge when learning is essentially explicit. They also supply further evidence for a partial dissociation between the neural substrates supporting conscious and non-conscious components of performance during recollection of a learned sequence.

**Sun, Ron et al. (2005)**

examined the interaction between implicit and explicit processes in skill learning, in contrast to the tendency of researchers to study each type in isolation. It highlights various effects of the interaction on learning (including synergy effects). The authors argue for an integrated model of skill learning that takes into account both implicit and explicit processes. Moreover, they argue for a bottom-up approach.

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approach (first learning implicit knowledge and then explicit knowledge) in the integrated model. A variety of qualitative data can be accounted for by the approach. A computational model, CLARION, is then used to simulate a range of quantitative data. The results demonstrate the plausibility of the model, which provides a new perspective on skill learning.

Marco Perugini (2005)\(^69\), investigated the Predictive models of implicit and explicit attitudes. Explicit attitudes have long been assumed to be central factors influencing behaviour. A recent stream of studies has shown that implicit attitudes, typically measured with the Implicit Association Test (IAT), can also predict a significant range of behaviours. This contribution is focused on testing different predictive models of implicit and explicit attitudes. In particular, three main models can be derived from the literature: (a) additive (the two types of attitudes explain different portion of variance in the criterion), (b) double dissociation (implicit attitudes predict spontaneous whereas explicit attitudes predict deliberative behaviour), and (c) multiplicative (implicit and explicit attitudes interact in influencing behaviour). This paper reports two studies testing these models. The first study (N=48) is about smoking behaviour, whereas the second study (N=109) is about preferences for snacks versus fruit. In the first study, the multiplicative model is supported, whereas the double dissociation model is supported in the second study. The results are discussed in light of the importance of focusing on different patterns of prediction when investigating the directive influence of implicit and explicit attitudes on behaviours.

J.P Maxwell et al. (2003)\(^70\), examined the role of working memory in motor learning and performance, three experiments explore the role of working memory in motor skill acquisition and performance. Traditional theories postulate that skill acquisition proceeds through stages of knowing, which are initially declarative but later procedural. The reported experiments challenge that view and support an independent, parallel processing model, which predicts that procedural and declarative knowledge can


be acquired separately and that the former does not depend on the availability of working memory, whereas, the latter does. The behaviour of these two processes was manipulated by providing or withholding visual (and auditory) appraisal of outcome feedback. Withholding feedback was predicted to inhibit the use of working memory to appraise success and, thus, prevent the formation of declarative knowledge without affecting the accumulation of procedural knowledge. While the first experiment failed to support these predictions, the second and third experiments demonstrated that procedural and declarative knowledge can be acquired independently. It is suggested that the availability of working memory is crucial to motor performance only when the learner has come to rely on its use.

Rosenbaum David A. et al. (2001)\(^1\), conducted a study on Acquisition of Intellectual and Perceptual-Motor Skills. Recent evidence indicates that intellectual and perceptual-motor skills are acquired in fundamentally similar ways. Transfer specificity, generatively, and the use of abstract rules and reflex like productions are similar in the two skill domains; brain sites sub serving thought processes and perceptual-motor processes are not as distinct as once thought; explicit and implicit knowledge characterize both kinds of skill; learning rates, training effects, and learning stages are remarkably similar for the two skill classes; and imagery, long thought to play a distinctive role in high-level thought, also plays a role in perceptual-motor learning and control. The conclusion is that intellectual skills and perceptual-motor skills are psychologically more alike than different accords with the view that all knowledge is performatory.

J.P. Maxwell et al. (2001)\(^2\), investigated the implicit benefit of learning without errors. Two studies examined whether the number of errors made in learning a motor skill, golf putting, differentially influences the adoption of a selective (explicit) or unselective (implicit) learning mode. Errorful learners were expected to adopt an explicit, hypothesis-testing strategy to correct errors during learning, thereby accruing a pool of verbalizable rules and exhibiting performance breakdown under dual-task conditions,

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characteristic of a selective mode of learning. Reducing errors during learning was predicted to minimize the involvement of explicit hypothesis testing leading to the adoption of an unselective mode of learning, distinguished by few verbalizable rules and robust performance under secondary task loading. Both studies supported these predictions. The golf putting performance of errorless learners in both studies was unaffected by the imposition of a secondary task load, whereas the performance of errorful learners deteriorated. Reducing errors during learning limited the number of error-correcting hypotheses tested by the learner, thereby reducing the contribution of explicit processing to skill acquisition. It was concluded that the reduction of errors during learning encourages the use of implicit, unselective learning processes, which confer insusceptibility to performance breakdown under distraction.

Rugg M. D. et al. (1998)\(^7\), investigated the dissociation of the neural correlates of implicit and explicit memory. One presentation of a word to a subject is enough to change the way in which the word is processed subsequently, even when there is no conscious (explicit) memory of the original presentation. This phenomenon is known as implicit memory. The neural correlates of implicit memory have been studied previously but they have never been compared with the correlates of explicit memory while holding task conditions constant or while using a procedure that ensured that the neural correlates were not 'contaminated' by explicit memory. Here we use scalp-recorded event-related brain potentials to identify neural activity associated with implicit and explicit memory during the performance of a recognition memory task. Relative to new words, recently studied words produced activity in three neuro anatomically and functionally dissociable neural populations. One of these populations was activated whether or not the word was consciously recognized, and its activity therefore represents a neural correlate of implicit memory. Thus, when task and memory contamination effects are eliminated, the neural correlates of explicit and implicit memory differ qualitatively.

Paul J. Reber et al. (1998)⁷⁴, conducted a study on Encapsulation of Implicit and Explicit Memory in Sequence Learning. Contrasts between implicit and explicit knowledge in the serial reaction time (SRT) paradigm have been challenged because they have depended on a single dissociation: intact implicit knowledge in the absence of corresponding explicit knowledge. In the SRT task, subjects respond with a corresponding key press to a cue that appears in one of four locations. The cue follows a repeating sequence of locations, and subjects can exhibit knowledge of the repeating sequence through increasingly rapid performance (an implicit test) or by being able to recognize the sequence (an explicit test). In our study, amnesic patients were given extensive SRT training. Their implicit and explicit test performance was compared to the performance of control subjects who memorized the training sequence. Compared with control subjects, amnesic patients exhibited superior performance on the implicit task and impaired performance on the explicit task. This crossover interaction suggests that implicit and explicit knowledge of the embedded sequence are separate and encapsulated and that they presumably depend on different brain systems.

Seger C. A. (1994)⁷⁵, looked after the implicit learning (IL) is non episodic learning of complex information in an incidental manner, without awareness of what has been learned. IL experiments use 3 different stimulus structures (visual, sequence, and function) and 3 different dependent measures of response modalities (conceptual fluency, efficiency, and prediction and control). IL may require a certain minimal amount of attention and may depend on attention and working memory mechanisms. The result of IL is implicit knowledge in the form of abstract (but possibly instantiated) representations rather than verbatim or aggregate representations. IL shows biases and dissociations in learning different stimulus structures. The dependence of IL on particular areas is discussed, some conclusions are drawn for modelling IL, and the interaction of implicit and explicit learning is considered.

Pascual-Leone A. et al. (1994) examined the modulation of cortical motor output maps during development of implicit and explicit knowledge. The excitability of the human motor cortex during the development of implicit and declarative knowledge of a motor task was examined. During a serial reaction time test, subjects developed implicit knowledge of the test sequence, which was reflected by diminishing response times. Motor cortical mapping with transcranial magnetic stimulation revealed that the cortical output maps to the muscles involved in the task became progressively larger until explicit knowledge was achieved, after which they returned to their baseline topography. These results illustrate the rapid functional plasticity of cortical outputs associated with learning and with the transfer of knowledge from an implicit to explicit state.

Arthur S. Reber et al. (1980), investigated the relationship between implicit and explicit modes in the learning of a complex rule structure. Two experiments with 91 undergraduates explored further the relationship between implicit (unconscious) and explicit (conscious) processes in the acquisition of complex knowledge. In Exp I, instructional set interacted with the extent to which the rule structure of the letter strings from a synthetic language was made salient in the stimulus array. In Exp II, explicit training had different effects depending on when during learning it was introduced. Results are discussed in terms of the complex, interactive roles that these 2 modes of apprehension have on acquisition of richly structured stimulus domains.

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