School of Psychology, Birkbeck College

Course PSYC044U (Psychobiology II.) WEEK **13**
May 17 2007

HUMAN LEARNING: Further comparisons between human, animal and machine learning

Relevant essays on the March 15th list

5. How is "conditioned fear" relevant to the understanding of the development and treatment of anxiety disorders"?

8. 'Apes cannot be taught language, but there is evidence that they have special abilities in the areas of social learning, imitation, and self-recognition.' Discuss.

9. Thorndike called himself a connectionist — is this just a co-incidence, or can comparisons be made between modern accounts of neural networks and previous theories of animal learning?

Notes
For some time in Cognitive Psychology and Cognitive Science, the study of human learning was de-emphasized (Glaser, 1990). On one hand, the influence of Chomskyean psycholinguists was in the direction that most important aspect of human cognition are determined by innate rather than learned factors (Chomsky, 1980, Piatelli-Palmarini, 1989). On the other hand the study of human information processing focused on models of human performance in brief experiments in areas such as perception and memory, with little attention paid to the gradual acquisition of skills (Newell and Simon, 1972; see Glaser, 1990). This is in stark contrast to the traditional view that the cultural transmission of knowledge is a unique and crucial feature of human societies, and also, for instance, to the widely held lay assumption that education and training hold the key to industrial and commercial competitiveness.

Clearly, however, interest in human learning has been retained in applied areas, such as educational psychology, and many areas of developmental psychology (Glaser, 1990; Hartley, 1998; Howe, 1998; Posner & Rothbart, 2005). There are several areas of human experimental psychology where the terminology of learning is still used, such as "implicit learning" (Berry, 1994; Seger 1994; Fletcher et al, 2000; Reed & Means, 2004), perceptual learning (Goldstone, 1998; Sekiyama et al, 2000; Ashby & Maddox, 2005; Driscoll et al., 2005) and varous kinds of motor skill learning (Marsolek and Field, 1999; Maxwell et al., 2001; Hikosaka et al., 2002; Tyc et al., 2005). There is also a growing area of psychobiological research in to motivation and emotion, where significant parellels, as well as differences, emerge in comparisons of human and animal learning (Cox et al., 2005; O'Doherty, 2004; Panksepp, 2005; Shultz, 2006; Paton et al., 2006; Padoa-Schioppa & Assad, 2006). Psychobiological parallels are also commonly appealed to in the case of theories of hippocampal functioning (Moses and Ryan, 2006; Foster and Wilson, 2006; see also week 9).

1. Human Cultural Learning and Social Cognition (Tomasello et al., 1993; Tomasello, 2001; Tomasello and Rakoczy, 2003; Tomasello et al., 2005; Moll & Tomasello, 2007)

A new version of the traditional theory that learning is an important feature of human cultures was been put forward by Tomasello et al. (1993) and Tomasello (2001) and has been modified by Tomasello and Rakoczy (2003) and Tomasello et al., (2005). First, there is an emphasis on the the importance of the "cultural ratchet" — knowledge is accumulated over time, and is passed on both across and within generations. The basic point is that **humans learn from each other**, in ways than non-human animals can not: human learning differs from animal learning because it is a more powerful and more influential process. The particular focus of this theory is the idea that human learning depends on social cognition, and that developmental changes in children's understanding of other people's point of view underlie their ability to acquire new skills and conventions from those around them. Three different kinds of cultural learning process are defined. (*see Table below*)

- **Imitative Learning** They reserve this term for the kind of imitative learning of novel object-direct actions that is usually first seen in human infants 9-14 month old. Neonatal copying of facial movements such as head turning and tongue protrusion counts only as "social matching" and some other kinds of action emulation in younger infants also do not qualify as true imitative learning in Tomasello et al's theory because it is not clear that they depend on the child understanding the intentions of the emulated adult.

- **Instructed Learning**. This corresponds to children being able to regulate their own behaviour vial the internalization of adult instructions. It is associated with self-monitoring skills or "metacognitive strategies".

- **Collaborative Learning**. Although younger children often collaborate in play, it is only at 6 or 7 that they can understand such recursive, perspective-taking mental states such as "Mary thinks that I think that John is cute" (p. 501) and the theory is that this allows for more sophisticated forms of learning during peer interactions.

Table 1 Major features of the three types of cultural learning (Tomasello et al., 1993 p. 153).

Cultural learning process	Social-Cognitive ability	Concept of person	Cognitive Representation
Imitative 9 months	Perspective-taking (e.g. joint attention, social referencing.	Intentional agents (0 order)	Simple (other's perspective)
Instructed (4 years)	Intersubjectivity (e.g. false-belief task, intentional deception).	Mental agent (1st order)	Alternating/ coordinated (other's and own perspective)
Collaborative (6 years)	Recursive intersubjectivity (e.g. embedded mental-state language	Reflective agent (2nd order)	Integrated (dyadic intersubjectivity).

Tomasello et al (1993, & 2003 & 2005) say that the imitative learning **of chimpanzees** "presents a complex and very interesting picture" but they do not believe that chimpanzees exhibit any of the above 3 kinds of cultural learning, since clearly they cannot internalize instruction and use it to regulate their own behaviour.

2. The reemergence of learning theory within instructional research.

This is the title of the article by Glaser (1990), who reviewed a variety of training projects designed to inculcate skills in such specialized areas as medical diagnosis, reading comprehension or computer programming. Most of these projects made use of Computer-Aided Learning (CAL). Even with computerized training programmes there are different approaches, which correspond to different aspects of human learning, but Glaser suggests that integrating the results from a wide variety of successful methods of systematic instruction might provide an all- encompassing theory of human learning.

Certain general principles emerge from his analysis

- Learning, as knowledge strengthening, results from error-free practice
- But failure or conflict may trigger new learning
- Feedback and guidance to the learner helps
- Learning takes place in the context of work on specific problems
- Explanation and modeling of problem-solving strategies helps

But there is still a difference between the two main kinds of training procedure

A. Progressive Mastery: a strict and progressive sequence of skills is laid down
B. Unstructured: the learner is given certain tools and then left alone.

Glaser believes that these different approaches may suit different kinds of task.

3. Anderson's Theory of Cognitive Skill Acquisition (Anderson, 1987, 2002; Anderson & Matessa, 1997)

Anderson's theory is one of the main ones discussed by Glaser (1990) It arises from work on the design of computer tutoring programmes for skills such as solving algebraic equations, computer programming in a particular language, or using a word-processor. Although these are uniquely human skills, Anderson's theory has a certain amount in common with traditional theories of animal learning, not least because he uses the terminology of learning, and says that his goal is to use his theory of learning *to account for differences in behaviour by differences in experience*.

Further, Anderson's is a "learning by doing" theory, and the units of learning in it are "condition-action pairs" which are acquired as a function of their previous consequences, which is reminiscent of Thorndike's "situation-response" connections (Thorndike, 1903). Anderson calls his condition-action pairs "productions.": "The ACT* theory offers a more abstract concept, the production, to replace the more concrete concept, the stimulus-response pair" (Anderson, 1987b, p. 198). However "ACT*" stands for "Adaptive Control of Thought", and Anderson's theory depends on the existence of "Declarative" subjectively available knowledge in long-term memory. The twist is that for Anderson, the process of learning, which can be mapped on to someone's progress from being a novice to being an expert at a particular cognitive skill, consists of the conversion of such verbally available knowledge into automatic habit-like rules — the expert has to think less about solving the problem than the novice.

The **major learning mechanism** posited by Anderson is ***knowledge compilation.*** This turns declarative knowledge ('knowing that' or 'knowing what') into proceduralized ('knowing how'). But this learning takes place at what Anderson calls the "mental algorithm" level, which corresponds to reportable states of working memory. So although learning is limited to small pairwise units these are introspectively available as "knowing what to do next". The learning mechanism is traditional in that the pairwise units (productions) **accumulate strength** as a result of practice, which as Glaser (1990) says is very like the supposed strengthening of associative bonds in stimulus-response learning theory. Little emphasis is placed on acquiring skills by understanding the principles behind them, and indeed Anderson (1987b) quotes experiments in which students given "how to do it" information learned to solve a computer-programming task more quickly than those given "why it works" information. But Anderson shares with Tomasello et al. (1993) the view that learning is a crucial and special aspect of human psychology —

> "Our most uniquely human attribute is our ability to acquire new abilities to deal with novel problems" [1987a, p475].
>
> "Most human skills and knowledge are not reinvented anew through raw induction by each generation but are passed from one generation to the next." [1987a, p474]

4. Conclusions

There is no general agreement about the nature of human learning and the role it plays. However there is current support both from developmental psychologists (Tomasello et al., 1993; Tomasello, 2001; Tomasello & Rakoczy, 2003; Leslie et al., 2005; Matsuzawa, 2007) and those concerned with methods for the training of specific cognitive skills (Anderson, 1987, 1990; 2002; Glaser, 1990; Howe, 1998; Howe et al., 1998; Hartley, 1998; Posner & Rothbart, 2005) for the position that learning is a crucial factor in human psychology. It is reasonable to conclude that additional cognitive capacities mean that the scope of human learning is radically different from that available to other species since people can profit from instruction, both that received from others and self-instruction. But there remain similarities between aspects of traditional theories of animal learning and certain current approaches to human learning.

It is noteworthy, for instance, that two theoretical papers published in the *Psychological Review* in 2001 supported modern versions of conditioning theories of the causation and treatment of neurotic disorders (Bouton et al., 2001; Ohman and Mineka, 2001: see also Battaglia & Ogliari, 2005 and Hermans et al., 2005).

Not suprisingly, reference to human learning is continues to be common in educational contexts (Chi et al., 2001; Hammond and Bennett,, 2002; Hartley, 1998; Howe, 1998; Posner & Rothbat, 2005). In particular, systematic studies of Computer-Aided Instruction have suggested that learning is promoted by practice and goal achievement (Issroff and Scanlon, 2002) and may in some cases be assisted by immediate feedback and the minimization of errors (Glaser, 1990).

In an entirely different way, in the theoretical analysis of how learning of complex skills can be achieved by simulated neural nets, connectionist modeling rests on the assumption that learning ultimately depends on the growth of low-level associations (Week 12).   However, most treatments of human learning include some reference to "high-level" abilities involved in systematic thought and the self-regulation of learning strategies (Glaser, 1990; Hartley, 1998; Tomasello et al., 1993, 2005; Tomasello & Rakoczy, 2003). In so far as these "high level" abilities are important in human learning, connectionist models are not helpful, except possibly for the purpose of explaining how the high-level abilities are implemented at the neural level.

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What Makes Human Cognition Unique? From Individual to Shared to Collective Intentionality

MICHAEL TOMASELLO AND HANNES RAKOCZY

Abstract: It is widely believed that what distinguishes the social cognition of humans from that of other animals is the belief-desire psychology of four-year-old children and adults (so-called theory of mind). We argue here that this is actually the second ontogenetic step in uniquely human social cognition. The first step is one year old children's understanding of persons as intentional agents, which enables skills of cultural learning and shared intentionality. This initial step is 'the real thing' in the sense that it enables young children to participate in cultural activities using shared, perspectival symbols with a conventional/normative/reflective dimension—for example, linguistic communication and pretend play—thus inaugurating children's understanding of things mental. Understanding beliefs and participating in collective intentionality at four years of age—enabling the comprehension of such things as money and marriage—results from several years of engagement with other persons in perspective-shifting and reflective discourse containing propositional attitude constructions.

By all appearances, the cognitive skills of human beings are very different from those of other animal species, including our nearest primate relatives. Human beings and only human beings cognize the world in ways leading to the creation and use of natural languages, complex tools and technologies, mathematical symbols, graphic symbols from maps to art, and complicated social institutions such as governments and religions. The puzzle is that other primates have created none of these things even though some—the great apes—are as closely related to humans as horses are to zebras, lions are to tigers, rats are to mice.

The solution to the puzzle is that such things as languages, symbolic mathematics, and complex social institutions are not individual inventions arising out of humans' extraordinary individual brainpower, but rather they are collective cultural products created by many different individuals and groups of individuals over historical time. And so if we imagine a human child born onto a desert island, somehow magically kept alive by itself until adulthood, it is possible that this adult's cognitive skills would not differ very much—perhaps a little, but not very much—from those of other great apes.

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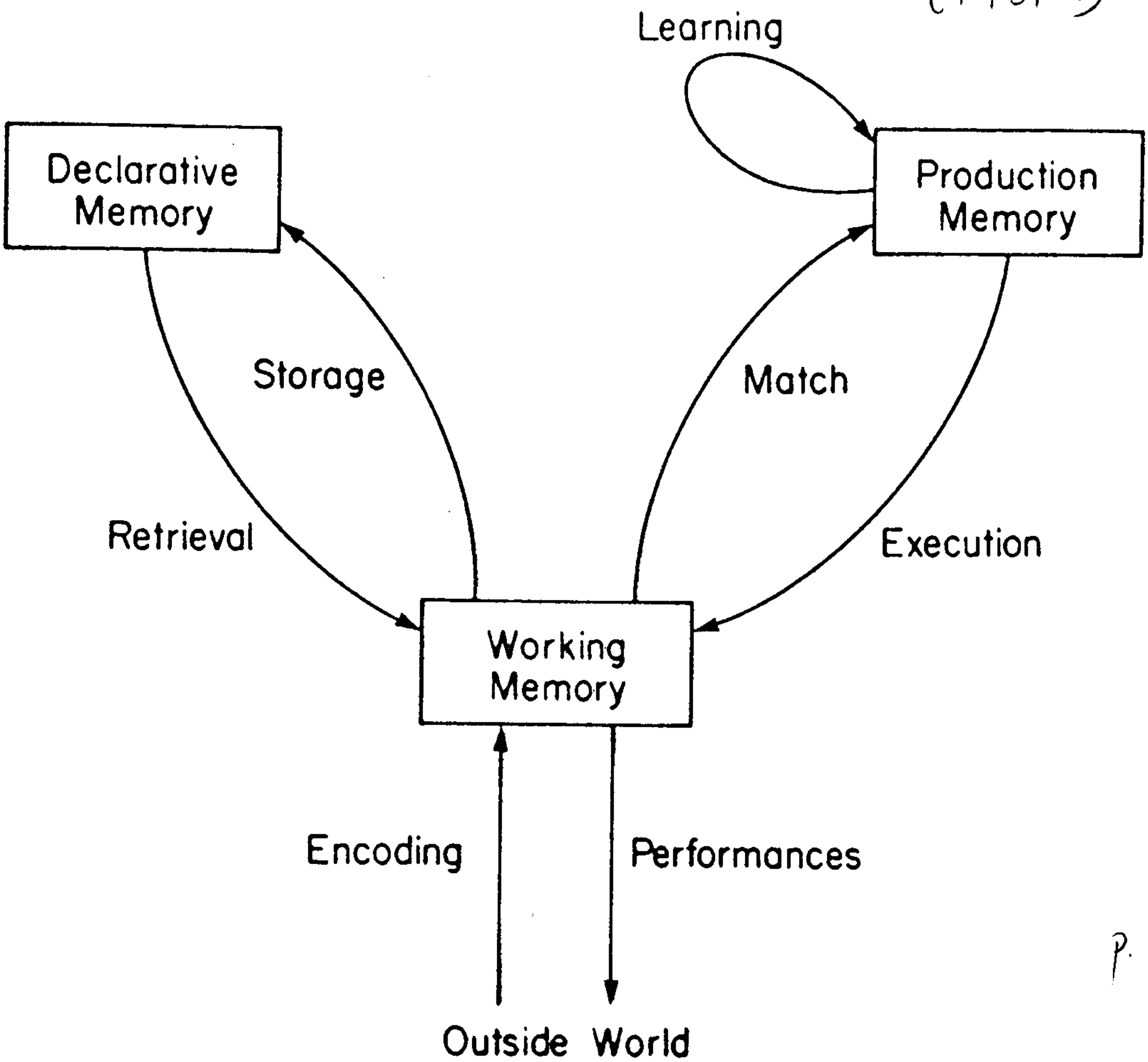
	Innate **(Nativism)** ***Predetermined cognition and reflexes, biological constraints on learning (if any).***	**Acquired** **(Empiricism)** ***Individual learning, including cultural transmission, formal training, and reasoning.***
Ideas: Complex cognitions, or relations between large units	Plato, Chomsky *et al* e.g. Piatelli-Palmarini, 1989; Pinker, 1994, 1998, Fodor 1983 Darwin, Sociobiologists (e.g. Wilson, 1975)	Aristotle Empiricist philosophers Some Behaviourists (e.g. Tolman) Anderson (1983, 1987, 2002, looking at HCI **Human-Computer Interaction:)** Computer Assisted Learning (CAL: Hartley, 1998)
Reflexes or *Connections:* Relations between small units	Darwin, Sherrington. Ethologists, (Tinbergen, Lorenz) Sociobiologists (e.g. Lazarus, 1987) and Behavioral Ecologists (e.g. Krebs & Davies, 1991)	Most behaviourists: Watson, Pavlov, Thorndike, Skinner Traditional associationists (e.g. Wm James) Neo-Connectionists, e.g. Rumelhart and McClelland (1986), Christiansen et al. (1999), Elman (2005)



p. 9

Figure 1. The overall architecture of the ACT* system.

long-term declarative memory. Matching production conditions to working memory serves to select production; when these productions execute, they deposit new information in working memory. Finally, new productions can be created by a learning process that operates on a history of what productions have been executed and what their consequences were.

There are two separate viewpoints about each of the components of the ACT* theory. On the one hand, we can analyze these components according to their abstract input–output specifications. This is like an abstract speci-

Hartley J. (1998) *Learning and Studying: A Research Perspective.* London: Routledge

Chapter 2: Learning theory in practice

Principles emphasised in behavioural psychology
p. 17

- *Activity is important*
- *Repetition, generalisation, discrimination are key notions*
- *Reinforcement is the cardinal motivator*
- *Learning is helped when the objectives are clear*

Principles emphasised in cognitive psychology
p. 18

- *Instruction should be well- organised*
- *Similarly instruction should be clearly structured*
- *The perceptual features of the task are important*
- *Prior knowledge is important*
- *Differences between individuals are important in how they affect learning*
- *Cognitive feedback gives information to learners about their success or failure concerning the task in hand*
- *Learning with understanding is better than learning by rote*

Principles emphasised in social and phenomenological psychology
p. 19

- *Learning is a natural process*
- *Social situations affect learning*
- *The purposes and goals of learning are important*
- *Choice, relevance and responsibility are important factors in learning*
- *Learning best takes place in a realistic setting*
- *Meaning is a personal thing*
- *Discussion about learning is important*
- *Self-regulation — monitoring one's learning — is an important skill*
- *Learners' conceptions of learning change*
- *Anxiety and emotion affect learning*

Hartley J. (1998) *Learning and Studying: A Research Perspective.* London: Routledge

Computer-aided Learning (CAL)(pp 100-106)

It is generally argued by supporters of new technology that CAL has several advantages over conventional classroom learning. These claimed virtues are that:

- learning is individualised;
- learning is self-paced;
- there can be instant feedback upon responding;
- the programs have been written by experts, and tried and tested before being published;
- the whole procedure can be cost-effective

Each of these 'advantages' however, is open to discussion, if not dispute. Thus:

- there is considerable evidence for the effectiveness of paired or groupwork in CAL;
- the pacing of the learning may be controlled by other (social) factors;
- the feedback is constrained by what is available in the program, and thus it cannot – unlike a teacher – take account of unforeseen responses;
- some programs are not well written or properly evaluated; and
- CAL is expensive.

Animal Learning, Human Learning and CAL — Conclusions

i. Some aspects of human learning are more similar to animal learning that others, in particular 'implicit learning' which is automatic and takes place without awareness (Reber, 1992; Seger, 1994). [see p 14]
ii. Automatic responses which are the result of sustained practice are in fact characteristic of human experts in a wide variety of skills (Anderson, 1987a; Ericsson and Lehmann, 1996; Howe *et al*, 1998)
iii. Some authorities on CAL, in particular Anderson (1987a, 1987b, 1990; see also Ramberg and Karlgren, 1998) discuss learning in a way which is reminiscent of Skinnerian shaping (Glaser, 1990) — learning is a result of accumulated error-free individual practice.
iv. However many other practitioners of CAL, and many other educational psychologists, emphasise uniquely human use of language (e.g. Tomasello *et al*, 1993)
v. These practitioners tend to emphasise self-monitoring, self-regulating, or self-organising skills, and "metacognitive strategies" (Tomasello *et al*, 1993; Tomasello, 1999; Glaser, 1990)
vi. The uniquely human aspects of learning within CAL include its use for collaborative and cultural learning (Rimmershaw, 1999; Hartley, 1998; Looi and Ang, 2000)

Seger, CA (1994) Implicit learning**.** *Psychological Bulletin,* Vol.115, No.2, Pp.163-196.

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

(Reber ,1992, argued that implicit learning is an evolutionarily early process and is more basic and robust. It is often retained over time. It is early developmentally, survives brain injury and cognitive insult including amnesia, and shows fewer individual differences

Seger's phrase is "evolutionary ancestor to explicit thought, and as such is considered to have a foundational role in cognition and to be closely related to learning in related animal species.

Ericsson, KA & Lehmann, AC (1996) Expert and exceptional performance - evidence of maximal adaptation to task constraints. *Annual Review of Psychology, Vol.47,* Pp.273-305

This paper argues that international levels of expert performance at cognitive and perceptual-motor skills are only attained after around **10 years of extended daily practice**. Examples are found, they say, in chess, computer programming, bridge, auditing, and physics as well as sports, dance and music.

Abstract Expert and exceptional performance are shown to be mediated by cognitive and perceptual-motor skills and by domain-specific physiological and anatomical adaptations. The highest levels of human performance in different domains can only be attained after around **ten years** of extended, daily amounts of deliberate practice activities. Laboratory analyses of expert performance in many domains such as chess, medicine, auditing, computer programming, bridge, physics, sports, typing, juggling, dance, and music reveal maximal adaptations of experts to domain-specific constraints. For example, acquired anticipatory skills circumvent general limits on reaction time, and distinctive memory skills allow a domain-specific expansion of working memory capacity to support planning, reasoning, and evaluation. Many of the mechanisms of superior expert performance serve the dual purpose of mediating experts' current performance and of allowing continued improvement of this performance in response to informative feedback during practice activities.]

Maxwell, J. P., Masters, R. S. W., Kerr, E., & Weedon, E. (2001). The implicit benefit of learning without errors. *Quarterly Journal of Experimental Psychology Section a-Human Experimental Psychology, 54*(4), 1049-1068.

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, 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.