Metadata of the chapter that will be visualized online

Chapter Title	Interactive Skills and Dual Learning Processes	
Copyright Year	2011	
Copyright Holder	Springer Science + Business Media, LLC	

Corresponding Author	Family Name	**Fu**
	Particle	
	Given Name	**Wai-Tat**
	Suffix	
	Division	Computer Science and Human Factors
	Organization	University of Illinois at Urbana-Champaign
	Address	201 N. Goodwin Avenue, Urbana-Champaign, IL, 61801, USA
	Email	wfu@illinois.edu
Author	Family Name	**Chin**
	Particle	
	Given Name	**Jessie**
	Suffix	
	Division	Computer Science and Human Factors
	Organization	University of Illinois at Urbana-Champaign
	Address	201 N. Goodwin Avenue, Urbana-Champaign, IL, 61801, USA
	Email	
Author	Family Name	**Dong**
	Particle	
	Given Name	**Wei**
	Suffix	
	Division	Computer Science and Human Factors
	Organization	University of Illinois at Urbana-Champaign
	Address	201 N. Goodwin Avenue, Urbana-Champaign, IL, 61801, USA
	Email	
Author	Family Name	**Vera Liao**
	Particle	
	Given Name	**Q.**
	Suffix	
	Division	Computer Science and Human Factors
	Organization	University of Illinois at Urbana-Champaign
	Address	201 N. Goodwin Avenue, Urbana-Champaign, IL, 61801, USA
	Email	

Interactive Skills and Dual Learning Processes

Wai-Tat Fu, Jessie Chin, Wei Dong, Q. Vera Liao
Computer Science and Human Factors, University of Illinois at Urbana-Champaign, Urbana-Champaign, IL, USA

Synonyms

Dual enrollment; Interactive abilities

Definition

Interactive skills refer to the general ability to interact with the external world to accomplish a task. A typical interactive task requires the person to look for relevant information and choose the right actions. The complexity of an interactive skill increases as (1) the uncertainty of the outcome of an action increases, (2) when the mapping between recognizable cues and actions becomes more complex, and (3) when there is interdependency between actions and outcomes. An interaction skill involves both explicit and implicit learning processes, and the effectiveness of each kind of process depends on the complexity of the skill. Explicit learning processes refer to processes that require focused attention and involve information that can be verbalized and communicated. Implicit learning processes do not require focused attention and involve information that cannot be easily verbalized and communicated.

Theoretical Background

An important aspect of interaction skill is the ability to utilize the right cues to select the right actions. Cues are patterns of information relevant for a task. Cues can be external and directly perceived (e.g., seeing a red light and deciding to stop), or they can be internal and need to be first encoded in memory and retrieved at a later time when they are needed (e.g., remembering where we park our car). The acquisition of an interactive skill involves the association between internal and external cues and actions. An interactive becomes more complex as the associations become probabilistic, interdependent, or both.

The simplest form of an interactive skill is cue-action association (the cue could be either internal or external). For instance, humans can learn to associate an action with a particular cue by observing how likely a cue-action association can reach a satisfying state of affairs (the law of effect; Thorndike 1911). A person can then learn to associate an action with the presence of an external cue, such that when the external cue is presented again, the right action can be selected. This simple form of interactive skill acquisition can be done by both explicit and implicit process. However, empirical studies show that explicit process is often suppressed when additional constraints are imposed, such as when a demanding external task is present which makes explicit learning of cue-action association difficult (Fu and Anderson 2008a, b; Keele et al. 2003).

An interactive skill becomes more complex when the cue-action associations are probabilistic, such that, for example, cue-action1 is 80% correct and cue-action2 is 20% correct in an environment. Learning in such probabilistic environment is difficult because the person cannot simply remember the last correct action (which can be either action1 or action2). Rather, the person needs to accumulate experiences and select actions that are in general more frequently correct in the past. This form of learning is often referred to as *reinforcement learning* (Sutton and Barto 1998). In general, reinforcement learning accumulates reward signal for each action after its execution, and select action that has the highest accumulated reward. Recent studies in neuroscience have shown that the reward signal in reinforcement learning resembles dopamine activities in the basal ganglia when humans are learning probabilistic cue-action associations (Waelti et al. 2001). Given that the basal ganglia is often considered to be responsible for implicit learning of cue-action association, it is often believed that learning of probabilistic cue-action association can be accomplished by implicit learning, and this hypothesis is shown to be consistent with results from behavioral studies.

The complexity of an interactive skill increases when immediate feedback is not available (e.g., when one is

Norbert Seel (ed.), *Encyclopedia of the Sciences of Learning*, DOI 10.1007/978-1-4419-1428-6,

navigating in an unfamiliar neighborhood). In that case, one has to learn from delayed feedback, and propagates feedback up to previous cue-action association. This creates a credit-assignment problem, as feedback is received only after an action sequence is executed, and it is not clear which particular action leads to the correct (or incorrect) outcome. In animal research, feedback is often implemented by explicit reward. However, explicit learning can occur without explicit feedback. For example, research in latent learning, in which rats learned the cognitive map of the maze implicitly and was able to later implement its knowledge without the presence of rewards (Tolman 1932).

Empirical studies show that there are distinct processes that perform the credit assignment of actions when learning from delayed feedback (Fu and Anderson 2008a, b). In the explicit process, cues and actions are first encoded into memory, and when the feedback is received, the cues and actions are retrieved and credits (positive or negative reward) can be assigned to them. In this kind of implicit learning, credits are first assigned to the cue-action that is closest to the feedback, and the credit will subsequently propagated back to earlier cue-action associations. This credit propagation process is shown to match well with a reinforcement learning process (Fu and Anderson 2006). Results from empirical studies show that the implicit reinforcement learning process can remain relatively effective even when attentional resources are drawn to a demanding secondary task (Keele et al. 2003).

Interactive skills become even more complex when there are interdependencies between sequential actions. Interdependency refers to the situations in which cues and actions in the environment are dependent on prior actions. In such situations, learning is difficult because one has to remember prior actions (and cues) before the right actions can be selected. Remembering prior cues or actions can be done by an explicit encoding process. However, when the explicit process is suppressed (e.g., by a demanding secondary task), learning of interdependent action sequences can sometimes be accomplished implicitly when external cues are present, which allow credits to propagate back from the final feedback to prior actions through the external cues. It has been shown that when consistent external cues are present, implicit reinforcement learning is sufficient to allow acquisition of interactive skills in which interdependency of actions exist. However, when consistent external cues do not exist, implicit reinforcement learning will fail, and people may simply fail to learn to select the correct action sequence in such situations (Fu and Anderson 2006).

Important Scientific Research and Open Questions

The idea that information is processed through two distinctive routes, one that requires explicit encoding, the other undergoes implicit reinforcement, is not limited to the acquisition of interactive skills. In fact, dual-processing theories can be found in a wide range of research, including research on persuasion, judgment and decision making, and neuroscience. For example, in the area of persuasion, researchers have studied how different information may lead to change in belief and attitudes (Petty and Cacioppo 1986). Although differences exist, these dual process models shared a fundamental consensus that external information cues are processed through a central route that systematically deliberate on the information content, and a peripheral route that relies more on heuristics, experience or/and emotion. In general, the explicit route demands more cognitive resources than the implicit route. When individuals lack either motivation or ability to perform systematical evaluation or deliberation on the information contents, they tend to rely more on implicit route to learn, make decisions, or change their attitude.

One important application of dual processing models is to understand how individual differences that are relevant to either of the two processes influence people's learning, attitude change, or decision-making outcomes. For example, aging is one of the factors being widely studied for its effects on explicit and implicit processes. Several lines of research provide robust evidence of age-related declines in deliberative/explicit system. It is shown that older adults performed generally worse in tasks that require systematical learning due to their lower information processing speed, age-related deficits in explicit memory, working memory, and executive functions. However, the age difference in implicit learning and memory is found only minimal. In terms of decision making, research showed that older adults tend to selectively use their explicit processes based on their level of motivation to make the decision; so when the information is less meaningful or relevant to them, they are less likely to explicitly process the contents to make the decision. Research also shows that older adults who are relatively more likely influenced by implicit cues are related to their emotions than do younger adults. However, the role of this implicit/affective processing is somewhat less clear since it may involve both explicit and implicit information processing, and more research is needed to clarify the interaction of implicit/affective processing and age-related factors such as decline in cognitive resource.

Although research has demonstrated the existence of the explicit and implicit learning processes, how exactly these processes are orchestrated in different situations is still unclear. It is not clear, for example, whether both processes would occur in parallel, and the relative effect of each kind of process will manifest itself in different situations, or whether one process may dominate the other one and influence behavior under different situations. More research is needed to understand how the two processes may be moderated by external (environmental) and internal (individual differences in cognitive abilities, experiences, etc.).

Cross-References

- ► ACT (Adaptive Control of Thought)
- ► Attention and Implicit Learning
- ► Basal Ganglia Learning
- ► Dual Process Models of Information Processing
- ► Implicit Sequence Learning
- ► Procedural Learning
- ► Reinforcement Learning

References

Ballard, D. H., Hayhoe, M. M., Pook, P. K., & Rao, R. P. N. (1997). Deictic codes for the embodiment of cognition. *The Behavioral and Brain Sciences, 20*, 723–742.

Fu, W.-T., & Anderson, J. R. (2006). From recurrent choice to skilled learning: A reinforcement learning model. *Journal of Experimental Psychology: General, 135*, 184–206.

Fu, W.-T., & Anderson, J. (2008a). Solving the credit assignment problem: Explicit and implicit learning of action sequences with probabilistic outcomes. *Psychological Research, 72*, 321–330.

Fu, W.-T., & Anderson, J. (2008b). Dual learning processes in interactive skill acquisition. *Journal of Experimental Psychology: Applied, 14*, 179–191.

Holroyd, C. B., & Coles, M. G. H. (2002). The neural basis of human error processing: Reinforcement learning, dopamine, and the error-related negativity. *Psychological Review, 109*, 679–709.

Keele, S., Ivry, R., Mayr, U., Hazeltine, E., & Heuer, H. (2003). The cognitive and neural architecture of sequence representation. *Psychological Review, 110*, 316–339.

Petty, R. E., & Cacioppo, J. T. (1981). *Attitudes and persuasion: Classic and contemporary approaches*. Dubuque: Wm. C. Brown.

Sutton, R. S., & Barto, A. G. (1998). *Reinforcement learning: An introduction*. Cambridge: MIT Press.

Thorndike, E. L. (1911). *Animal intelligence: Experimental studies*. New York: Macmillan.

Tolman, E. C. (1932). *Purposive behavior in animals and men*. New York: Century psychological series.

Waelti, P., Dickinson, A., & Schultz, W. (2001). Dopamine responses comply with basic assumptions of formal learning theory. *Nature, 412*, 43–48.

Author Query Form

Encyclopedia of the Sciences of Learning
Chapter No: 1633

Query Refs.	Details Required	Author's response
AU1	"Petty and Cacioppo 1986" is cited in text but not given in the reference list. Please provide details.	