Research News

Implicit learning revealed by the method of opposition

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Complex information, such as that required for motor skills, can be learned implicitly, without awareness. Much debate has centered on the appropriate methods for proving that implicit learning is not influenced by explicit awareness. A recent study by Destrebecqz and Cleeremans has provided compelling evidence for implicit sequence learning without awareness by using the 'method of opposition'.

Imagine you are riding a bicycle, and you start falling to the right. How would you avoid the impending crash? Many cyclists say they would compensate by leaning towards the left, but that action would precipitate the fall. When responding to the same situation while actually riding a bicycle, these same cyclists would turn their handlebars in the direction of the fall. The example (from Ref. 1) highlights the distinction between implicit and explicit knowledge*. Implicit learning refers to the ability to learn complex information (e.g. skills such as bicycle riding) in the absence of explicit awareness. Anecdotes such as the bicycle example offer subjectively compelling demonstrations for the existence of implicit forms of knowledge that are distinct from (and possibly in conflict with) explicit knowledge, but the existence of such learning without awareness has been difficult to prove scientifically.

Learning to ride a bicycle requires the precise coordination of multiple movements. One must properly sequence leg contractions and extensions with corresponding adjustments of the body axis. Many researchers of implicit learning have adopted the serial reaction time (SRT) task[2] as a simple example of sequential learning that is amenable to laboratory control (reviewed in Refs 3,4). Experimental participants typically view a stimulus appearing at different visual locations in a seemingly random pattern and press response keys corresponding to those locations as quickly as possible. Learning is inferred from the observation that response times become faster when stimulus locations follow a repeating sequence, compared with random control conditions.

'[These] results provide the best evidence to date that sequence learning can proceed unconsciously...'

SRT learning is often claimed to be implicit because participants demonstrate little or no explicit knowledge of the structure of the sequence. Lack of explicit knowledge is typically demonstrated through verbal report[5], testing explicit memory for parts of the sequence[6], or testing the ability to generate the sequence from memory. The 'generation task', for example, is often given after SRT learning to assess explicit knowledge[2]: participants are informed of the repeating SRT sequence and asked to generate it from memory by pressing the response keys in the order of the sequence. Learning is claimed to be implicit when SRT response times during the test are faster for sequence than for random trials, but generation accuracy is no better than chance. Although studies claiming to demonstrate implicit SRT learning abound, few have unambiguously refuted the charge of critics who contend that performance improvements are merely attributable to traces of explicit knowledge that have gone undetected by procedures such as the generation task[7,8].

The method of opposition

A fundamental problem with the measurement of unconscious processes is known as the process purity problem[9–11]. When we learn, remember or perceive something, it is likely that both explicit (consciously accessible) and implicit (unconscious) processes are at work, so our behavior will usually reflect a mixture of both. The usual method of studying unconscious cognitive processes is by attempting to design experimental tasks that uniquely tap implicit processes. However, because implicit and explicit processes are so intertwined, it is usually futile to attempt to design such 'process-pure' tasks (this has been called the 'process-purity problem'). Thus, with regard to sequence learning, the SRT task cannot be considered a pure measure of implicit learning, and the generation task cannot be considered a pure measure of explicit learning.

Within the domain of human memory, Larry Jacoby developed an ingenious technique for sidestepping the process-purity problem and estimating the relative contributions of conscious and unconscious processes to performance[10,12]. Jacoby noted that conscious and unconscious processes often act together to determine performance. For example, if asked whether Sebastian Weisdorf or Satchel Paige is a member of the National Baseball Hall of Fame, one might correctly answer 'Satchel Paige' based on explicit memory for that fact, or because implicit memory processes make his name seem more familiar[13]. Both conscious and unconscious processes might increase the likelihood of selecting the correct name, so it is difficult to separate their individual contributions. Jacoby and colleagues reasoned that conscious and unconscious processes might be separated if they were placed in opposition such that they would influence performance in opposite ways.

Consider Jacoby's experiment in which participants first studied a list of names of non-famous people[13]. After seeing the study list, participants were informed that the names were all non-famous. Next, participants were given a test list in which non-famous names from the original list (e.g. Sebastian Weisdorf) were intermixed with moderately famous names (e.g. Satchel Paige), and they were asked to judge whether or not each name was famous. This fame judgment test placed implicit and explicit memory for the studied names in opposition. If participants explicitly recollected 'Sebastian Weisdorf' from the list, they would correctly answer '*non-famous*'. If explicit recollection failed, on the other hand, and implicit processes made Sebastian Weisdorf seem familiar, they would incorrectly answer '*famous*'. When explicit memory was limited by deliberately dividing the participant's attention during the study list, Jacoby *et al.* found that participants were more likely to

* For the present purposes, the terms explicit/conscious/aware and implicit/unconscious/unaware are used interchangeably, but some researchers have adopted subtly different definitions.

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say that non-famous names such as Sebastian Weisdorf were '*famous*' when they appeared on the initial study list than when they did not. Because explicit memory would lead to the opposite pattern, this experiment revealed an unconscious influence of memory on performance.

The method of opposition assumes that conscious and unconscious processes differ in terms of intentional control[10,14]. When information is consciously accessible, people can control how that information is used (e.g. responding '*non-famous*' to names that are recollected from the study list). However, because people lack control over the use of unconscious information, it can influence a person's behavior in ways that can conflict with a person's true intentions (e.g. responding '*famous*' to a name that is merely familiar because it was on the study list).

Applying the method of opposition to sequence learning

The method of opposition was recently applied to SRT learning in an experiment by Destrebecqz and Cleeremans[15]. In their study, response time decreased across 12 blocks of SRT trials with a repeating sequence, and was significantly faster than response time on a thirteenth control block. The performance improvement indicated that participants learned something about the sequence, but was this learning implicit? After completing the SRT task, participants were told that a sequence was hidden within the SRT trials, and they completed a generation task to estimate explicit knowledge of the sequence, under two conditions that placed implicit and explicit knowledge in opposition. In the 'inclusion' condition, participants were asked to press response keys in an order that followed the sequence in the SRT task (as is usual in the generation task). In the 'exclusion' condition, participants were asked to press response keys in an order that did not follow the sequence. If a person has good explicit knowledge of the sequence, performance in the inclusion condition would regularly follow the sequence, but exclusion performance would not. Thus, explicit knowledge would lead to a difference between inclusion and exclusion performance in the proportion of trials in which the correct SRT sequence was generated (inclusion > exclusion). People with no explicit knowledge would tend to generate the sequence equally often on inclusion and exclusion trials (inclusion = exclusion) because they have no control over how the learned sequence information influences behavior.

Two groups of participants were tested in conditions that led to different levels of explicit knowledge. The 'RSI' group, who were given a brief pause between each response and the appearance of the next stimulus [response-to-stimulus interval (RSI) = 250 ms], showed a large difference between sequence and random SRT trials, as well as generating the sequence significantly more often for inclusion than exclusion trials. Thus, the RSI group learned the sequence, but that learning was at least partially attributable to explicit knowledge (inclusion > exclusion). The no-RSI group (RSI = 0) also was faster for sequence than random SRT trials, but their generation performance indicated that the learning was implicit. Participants in the no-RSI group generated the sequence equally often in the inclusion and exclusion conditions (inclusion = exclusion). In addition, the participants' ability to discriminate between parts of the sequence in a final recognition test was consistent with their generation performance. RSI participants could discriminate parts of the actual sequence from non-sequence distractors, but no-RSI participants could not.

Destrebecqz and Cleeremans's results provide the best evidence to date that sequence learning can proceed unconsciously (implicitly), but some qualifications are in order. First, as was well demonstrated by the RSI condition, SRT learning is not always implicit, so researchers must guard against 'explicit contamination' in each and every case in which conscious accessibility is at issue. Second, inferences that follow from Destrebecqz and Cleeremans's application of the method of opposition are somewhat limited. Their technique provides a good indication of whether or not explicit knowledge is present within a given experimental group. However, students of implicit learning are particularly interested in discovering the characteristics of unconscious learning processes themselves. For example, the results suggest that explicit knowledge increases when an RSI is used, but it remains uncertain how implicit processing is influenced by the RSI. Jacoby and colleagues have extended their opposition paradigm to directly estimate unconscious influences (the 'process-dissociation procedure'), but these estimates depend upon making some critical assumptions about the relationship between conscious and unconscious processes that have been the subject of much debate[12,16]. Destrebecqz and Cleeremans should be applauded for not indiscriminately applying the full process-dissociation procedure to this new domain, but future developments along these lines could be invaluable for furthering our understanding of implicit sequence learning.

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