Pretend Play and Learning

▶ Play and Its Role in Learning

Previous Experience

▶ Pre-exposure Effects on Spatial Learning

Primary Abilities

▶ Folk Knowledge and Academic Learning

Primary Memory

▶ Working Memory and Information Processing

Prime

▶ Reinstatement of Learning

Primed Recall

▶ Cued Recall

Priming

▶ Cueing

Priming, Response Learning, and Repetition Suppression

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Synonyms

fMR-adaptation; Implicit memory; Stimulus–response binding

Definition

Priming refers to a change in behavioral response to a stimulus following prior exposure to that stimulus. This behavioral change can manifest as a change in reaction time (RT), response accuracy, or response bias, and can be either positive or negative in direction. For example, responses could be faster and more accurate for a repeated relative to a novel stimulus (positive priming) or slower and less accurate (negative priming). *Repetition Suppression* (RS), as measured by *functional magnetic resonance imaging* (fMRI), refers to a decreased response for repeated relative to novel stimuli within certain brain regions, and often coincides with positive priming. Several types of learning have been associated with priming and RS. One such type is *response learning*, whereby, when a stimulus is first encountered and a response enacted, a direct *stimulus–response* (S-R) binding is formed between them. When the stimulus is repeated, this S-R binding can be retrieved. If the task performed on the repeated stimulus requires a similar response to when it was first encountered, the retrieved S-R binding can facilitate processes relating to the selection of an appropriate response. Such response retrieval is thought to lead to a decreased brain response in cortical regions that perform response-selection processes (RS) and accelerate behavioral responses (positive RT priming). Conversely, negative priming, and possibly increased responses in brain regions that perform response-selection, can be seen when the retrieved response is incongruent with the response currently required.

Theoretical Background

Multiple forms of learning have been hypothesized to underlie priming and RS. One of the dominant views within the cognitive neuroscience literature is the proposal that positive priming reflects the facilitation of specific mental processes recruited during the first and any subsequent presentation of a stimulus (Witherspoon and Moscovitch 1989). For example, following the presentation of a visual object in the context of a semantic categorization task (e.g., is the object man-made?), specific mental processes will be recruited. These processes are likely to include, at a minimum, the perceptual identification of the visual object – a *perceptual process* – as well as the retrieval of semantic information relating to the task – a *conceptual process*. If the same processes are reengaged on a subsequent presentation, these processes are thought to be facilitated. The first presentation of a stimulus therefore "greases the tracks," setting the stage for future facilitation. If a subsequent presentation of the stimulus uses the same tracks (same component processes), then facilitation will occur. If a subsequent presentation of the stimulus uses different tracks, facilitation will not occur. The amount of facilitation is therefore thought to be related to the amount of overlap in processing between the first and subsequent encounter with the stimulus. Under this *component process* view, RS reflects the facilitation of these processes (i.e., faster processing or fewer neurons involved, resulting in less brain activity). Therefore, it is argued that RS occurs within the brain regions that perform these specific mental processes. This neural facilitation is thought to lead to faster and more accurate behavioral responses, in other words positive priming.

An alternative to this view is that priming and RS result from the encoding and retrieval of direct stimulus–response (S-R) bindings (Logan 1990). Here, each encounter with a stimulus is thought to entail the formation of an S-R binding. Assuming that the repeated stimulus is encountered in a similar context to a previous presentation (e.g., in the same experimental task), the retrieval of a previously encoded S-R binding provides predictive information about the response that should be made. As such, S-R retrieval allows for the facilitation of processes relating to the selection of a response. This facilitation of response-selection processes should result in RS within the brain regions that perform these processes, leading to faster response times – positive priming. However, such S-R retrieval may not always facilitate response-selection. In a situation where the retrieved S-R binding is no longer appropriate, for example, in the context of a new experimental task, the retrieved response might interfere with response-selection. This is a situation in which negative priming can occur (i.e., slower or less accurate responses for repeated stimuli) and may relate to increases in neural activity for repeated stimuli in brain regions that perform response-selection processes, so-called *repetition enhancement (RE)*. As such, response learning effects can be positive or negative depending on the match between the retrieved response and the response currently required.

Ultimately, priming is likely to result from a combination of multiple independent sources. For example, if an object is repeated in the context of the same experimental task, it is likely that facilitation of multiple perceptual and conceptual processes will occur, in addition to facilitation of response-selection by S-R retrieval. Therefore, when considering a behavioral measure like RT, it should be remembered that it reflects the outcome of all these contributions. Priming should therefore reflect the sum total of these facilitatory and possible interference effects. In contrast, at the neural level, RS and RE can be seen across multiple cortical regions, from relatively low-level visual regions in the occipital lobe to semantic and premotor regions in the frontal lobe. As such, fMRI offers a means to spatially separate these multiple contributions to priming.

Important Scientific Research and Open Questions

Much of the fMRI literature on RS has focused on the specific brain regions and component processes that might be facilitated. In more recent years, however, there has been a renewal of interest in response learning contributions to RS. Logan (1990) was one of the first to propose that priming may stem from the rapid encoding and retrieval of S-R bindings. When a stimulus is first presented, Logan proposed that a response is generated by recruiting specific component processes, which he referred to as an *algorithmic route*. Each subsequent encounter with the stimulus however can benefit from an additional S-R, or *instance*, retrieval route, such that the final response is based on a "race" between these routes. In fact, he proposed that multiple races occur between the algorithmic route and each independently encoded S-R binding. Thus, as the number of available S-R bindings increases, so should the amount of priming. In support of this idea, Logan showed that, when the same response was required across presentations, the mean and variance of RTs decreased as a function of number of presentations in the manner predicted by an independent race. When a switch in response occurred between presentations, however, priming was reduced. In these situations, Logan proposed that S-R retrieval was effectively ignored and only the algorithmic route could enter the race, thereby removing priming completely.

Just as Logan (1990) showed that priming is reduced when a response is switched between presentations of a stimulus, Dobbins et al. (2004) showed that the RS in most brain regions decreases when the response is switched between presentations. Here, when the categorization task performed on visual objects (e.g., is it "bigger than a shoe box?") was kept constant, repeated objects produced RS in several brain regions within the occipital, temporal, and frontal lobes. Importantly, when the task was reversed between presentations (e.g., is it "smaller than a shoe box?"), RS was reduced in these regions, or even abolished in some occipital and temporal regions normally associated with perceptual processing. The importance of this finding was that RS in these regions, even relatively early visual-processing regions, may not reflect more efficient component processes (greased tracks), but rather a bypassing or curtailing of activity in those regions owing to rapid, independent retrieval of S-R bindings. This alternative S-R interpretation therefore questioned previous fMRI experiments that had used RS to infer the presence of specific component processes in specific brain regions.

As previously stated, however, priming and RS are likely the result of multiple independent forms of learning. In support of this, Horner and Henson (2008) recently revealed a dissociation between RS in the temporal and frontal lobes. Contrary to Dobbins et al., they found that RS in occipitotemporal cortex was *not* affected by any switches in response between repeated presentations, an effect confirmed by subsequent studies. In other words, RS in this brain region did not care whether a response was repeated or reversed between presentations. These data suggest that RS in this region is not driven by the retrieval of S-R bindings, but rather is likely to reflect the traditional interpretation in terms of facilitated perceptual (or conceptual) component processes. On the other hand, RS in regions of the frontal lobe was shown to be sensitive to switches in response between presentations (consistent with Dobbins et al. 2004). They therefore suggested that it is RS in these regions that reflects the facilitation of response-selection processes from the retrieval of S-R bindings. These data therefore provided evidence that RS can result from multiple forms of learning.

So far, we have discussed evidence for the facilitation of response-selection processes when an appropriate S-R binding is retrieved. To what extent are response-selection processes affected by the retrieval of an inappropriate S-R binding? In Logan's theory, previous S-R bindings are simply ignored if the task has changed, in which case, neither positive nor negative priming should be seen. In other words, these stimuli should be treated as if they were being presented for the first time. Alternatively, it may not be possible to ignore an inappropriate response, such that it could actively interfere with response-selection. If this were the case, then one would expect to see negative priming, and greater neural activity in the frontal lobe (i.e., RE), as neural activity is required to overcome the interference caused by retrieving an inappropriate response.

In fact, evidence has shown that negative priming can occur when a response is switched between presentations (Hommel 1998). Furthermore, this negative priming effect has also been seen despite stimuli being unattended on their first presentation. In such "negative priming" paradigms, two stimuli are presented at the same time and participants are required to attend and respond to only one, ignoring the other. When the previously ignored stimulus is then repeated and the participant asked to attend and respond to it, negative priming can be seen. Although this negative priming effect is likely to result from multiple forms of learning (as with positive priming), response learning has again been shown to play a role (Rothermund et al. 2005). It is thought that when the two stimuli are first presented, the response made to the attended stimulus also becomes automatically bound to any concurrent stimuli, even if they are to be ignored. In other words, the response becomes bound to all stimuli that are present at the time the response is made. When the previously ignored stimulus is presented again and participants are required to attend to it, the response previously bound to it can be retrieved and interfere with the current response required, causing negative priming.

Although priming data clearly point to interference and negative priming following the retrieval of inappropriate S-R bindings, conclusive fMRI evidence for RE following the retrieval of an inappropriate S-R binding has not yet been found. If the retrieval of an inappropriate S-R binding does lead to interference of response-selection processes, it would be predicted that this RE should occur in the same frontal lobe regions that show RS when responses are repeated. Future testing on this prediction would strengthen the claim that repetition effects in the frontal lobe reflect facilitation or interference following the retrieval of an S-R binding.

Cross-References

► Affective Priming and Learning
► Attention and Implicit Learning
► Explicit and Procedural-Learning-Based Systems of Perceptual Category Learning

References

Dobbins, I. G., Schnyer, D. M., Verfaellie, M., & Schacter, D. L. (2004). Cortical activity reductions during repetition priming can result from rapid response learning. *Nature, 428*(6980), 316–319.

Hommel, B. (1998). Event files: Evidence for automatic integration of stimulus-response episodes. *Visual Cognition, 5*, 183–216.

Horner, A. J., & Henson, R. N. (2008). Priming, response learning and repetition suppression. *Neuropsychologia, 46*(7), 1979–1991.

Logan, G. D. (1990). Repetition priming and automaticity: Common underlying mechanisms? *Cognitive Psychology, 22*, 1–35.

Rothermund, K., Wentura, D., & De Houwer, J. (2005). Retrieval of incidental stimulus-response associations as a source of negative priming. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 31*(3), 482–495.

Witherspoon, D., & Moscovitch, M. (1989). Stochastic independence between two implicit memory tasks. *Journal of Experimental Psychology. Learning, Memory, and Cognition, 15*(1), 22–30.

Primitives

► Human Feature Learning

Print-Based Learning

► Literacy and Learning

Prior Knowledge Principle

► Role of Prior Knowledge in Learning Processes

Private Schooling

► Homeschooling and Teaching

Private Speech

Self-directed talk, in other words, utterances produced to self and not others. Vygotskyan psycholinguistic theory and research link private speech to the sociocognitive processes of language learning, more specifically to the internalization of social speech for individual cognitive purposes. Private speech is used by children and adults for purposes of maintaining or regaining self-regulation (e.g., to aid in focusing attention or problem solving).

Proactive Learning

► Adaptive Proactive Learning with Cost-Reliability Trade-off

Probabilistic Approaches

► Bayesian Learning

Probabilistic Categorization

► Multiple-Cue Probability Learning