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THEORETICAL REVIEW

What is learning? On the nature and merits of a functional definition of learning

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Abstract Learning has been defined functionally as changes in behavior that result from experience or mechanistically as changes in the organism that result from experience. Both types of definitions are problematic. We define learning as ontogenetic adaptation—that is, as changes in the behavior of an organism that result from regularities in the environment of the organism. This functional definition not only solves the problems of other definitions, but also has important advantages for cognitive learning research.

Keywords Learning · Conditioning · Definition

Learning has been a central topic in psychological research virtually since the inception of psychology as an independent science (e.g., Ebbinghaus, 1885/1962; Thorndike, 1911). During the largest part of the previous century, it was even the most intensely studied topic in psychology. Also, today, questions about learning are addressed in virtually all areas of psychology. It is therefore surprising to see that researchers are rarely explicit about what they mean by the term *learning*. Even influential textbooks on learning do not always contain a definition of its subject matter (e.g., Bouton, 2007; Schwartz, Wasserman, & Robbins, 2002). Perhaps this state of affairs results from the fact that there is no general agreement about the definition of learning. To some extent, the lack of consensus about the definition of learning should not come as a surprise. It is notoriously difficult to define concepts in a satisfactory manner, especially concepts that are as broad and abstract as the concept of *learning*. However, it may be unwise to conclude that definitional issues should thus be ignored. It is likely that all learning researchers carry with them some idea of what learning is. Without at least an implicit sense of what learning is, there would be no reason to devote one's time and energy to studying it. Addressing definitional issues in an explicit manner can thus help avoid misunderstandings and facilitate communication among learning researchers.

In this article, we hope to contribute to the debate about the definition of learning by putting forward a detailed functional definition of learning. Our definition is inspired by the work of Skinner (1938, 1984; see Chiesa, 1992, 1994, for excellent analyses of Skinner's ideas), but as far as we know, it has not yet been proposed in the current form. We examine in detail how our definition solves some of the problems of alternative definitions of learning. Furthermore, we argue that because of its functional nature, our definition actually promotes, rather than hinders, cognitive research on the mental mechanisms that mediate learning. Before we address these issues, we provide a brief overview of the merits and shortcomings of other definitions of learning that are available in the literature. This allows us to clarify the unique elements of our functional definition and the problems that it solves.

Learning as a change in behavior versus a determinant of changes in behavior

As was noted by Lachman (1997), most textbook definitions of learning refer to learning as a change in behavior that is due to experience. This is essentially a very basic functional definition of learning in that learning is seen as a function that maps experience onto behavior. In other words, learning is defined as an effect of experience on behavior.

Many researchers have claimed that such a simple functional definition of learning is unsatisfactory (e.g., Domjan, 2010; Lachman, 1997; Ormrod, 1999, 2008). Most important, it has been argued that a simple functional definition has difficulties dealing with the fact that changes in behavior are neither necessary nor sufficient for learning to occur. First, latent learning effects suggest that changes in behavior

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are not necessary for learning to occur. Ever since Tolman and Honzik (1930), we know that experiences at time 1 (e.g., exploring a maze in which no food is available) that do not appear to have any effect on behavior at that point in time can suddenly influence behavior at a subsequent time 2 (e.g., facilitate learning of the location of food once it is made available in the maze). Hence, organisms seem to learn something at time 1 that is expressed in behavior only at time 2. The learning that occurs at time 1 is latent in that it does not yet produce a change in behavior at that point in time. Second, it has been argued that observing a change in behavior is not sufficient to infer the presence of learning because (1) not all effects of experience on behavior can be regarded as learning and (2) not all changes in behavior are due to experience. Certain individual experiences (e.g., the occurrence of an unexpected stimulus such as a loud bang) result in an immediate and transient change in behavior. It seems counterintuitive to refer to these changes in behavior as instances of learning. Other temporary changes in behavior, such as changes that are due to fatigue or a lack of motivation, should also fall outside the definition of learning. Moreover, behavior can change as the result of genetic factors. Hence, learning cannot be defined merely in terms of changes in behavior.

Although these criticisms of a simple functional definition of learning are widespread (e.g., Domjan, 2010; Lachman, 1997; Ormrod, 1999, 2008), not all of them are valid. For instance, the definition does not imply that changes in behavior are sufficient to infer the presence of learning. A change in behavior is an instance of learning only if it is caused by some experience of the organism. Hence, behavior changes that are due to factors other than experience (e.g., genetic factors) do not count as instances of learning. Nevertheless, it is true that a simple functional definition of learning is overinclusive because it encompasses changes in behavior that are due to individual experiences such as hearing a loud bang. What is most crucial for present purposes is that the identification of the (alleged) problems of a simple functional definition led to the proposal of other definitions of learning. Most of these alternative definitions have in common the assumption that learning involves some kind of change in the organism, and this change is necessary but not sufficient for observing a change in behavior. For instance, in his highly influential textbook, Domjan defines learning as an enduring change in the *mechanisms* of behavior (p. 17). Likewise, Lachman typifies learning as a process that underlies behavior. He argues that learning should not be confused with the product of this process—that is, the change in behavior. The change in the organism that is assumed to lie at the core of learning is sometimes described at a very abstract level (e.g., merely as some kind of internal change; see Hall, 2003) but sometimes also as involving a specific mental process (e.g., the formation of associations; see Ormrod, 2008). Because learning is seen as only one of many mechanisms that determine behavior, it follows that changes in behavior are neither necessary (because other determinants of behavior can block the impact of learning on behavior—e.g., a lack of motivation) nor sufficient (because other determinants of behavior might be responsible for a change in behavior—e.g., the genetic makeup of an organism) to infer the presence of learning.

Although many of these alternative definitions of learning still refer to the impact of experience on behavior, they are no longer functional in a strict sense of the word, because they refer to the mechanism that mediates the impact of experience on behavior. Mechanistic approaches in psychology aim to uncover the mechanisms that drive behavior—more specifically, the parts of a mechanism, the organization of the parts, and how each part operates (Bechtel, 2005, 2008). For present purposes, it is important to note that mechanistic accounts of behavior imply that some part of the mechanism operates at the time of the behavior change. In other words, mechanistic accounts imply the presence of contiguous causes of behavior: If a behavior change occurs at time 2, there needs to be an element that is present immediately before time 2 and that causes the change in behavior at time 2 (Chiesa, 1992, p. 1293). From such a mechanistic perspective, the phenomenon of latent learning challenges a definition of learning as the *contiguous causal* effect of experience on behavior. The experience at time 1 that is assumed to cause the change in behavior at time 2 is no longer present immediately before that change in behavior occurs. Hence, the experience cannot be a contiguous cause of the change in behavior. To solve this conundrum, it is assumed that the experience causes some change in the organism that somehow lasts over time and can function as the contiguous cause of the change in behavior that occurs at a later moment in time. Hence, a mechanistic approach to behavior seems to require a definition of learning in terms of a change in the organism.

Mechanistic definitions of learning, however, also have important downsides. The assumption that a change in behavior is neither necessary nor sufficient to infer the presence of learning implies that changes in behavior do not provide a good index for inferring the presence of learning. Instead, verifying a mechanistic definition ultimately requires the detection of some kind of change in the organism that is produced by some kind of experience. This is very difficult to achieve because it is, at least currently, not clear what exactly changes in the organism as a result of experience or how one can determine that such a change in the organism has occurred. Hence, a mechanistic definition of learning makes it difficult to identify instances of learning and, thus, to study learning. The only option seems to be to revert back to the observation of changes in behavior.

However, because the change in the organism is neither a necessary nor a sufficient determinant of behavior, there cannot be a one-to-one relation between the change in the organism and a particular change in behavior. Therefore, it is unlikely that one can find an observable change in behavior that provides a proxy for the change in the organism that is assumed to define learning (De Houwer, 2011).

A mechanistic definition of learning not only complicates the identification of instances of learning; it also fails to provide a straightforward way to define and differentiate different subclasses of learning (e.g., classical conditioning vs. operant conditioning). One could argue that different subclasses of learning involve different kinds of changes in the organism (e.g., the formation of stimulus–stimulus associations vs. response–stimulus associations in memory). However, it seems even more difficult to infer that an organism has changed in a specific kind of way (e.g., that a stimulus–stimulus association has formed in memory) than to determine that the organism has changed in some general kind of way. Hence, mechanistic definitions of subclasses of learning appear difficult to verify. A second problem with defining different subclasses of learning in terms of different kinds of changes in the organism is that it implies a priori assumptions about the mechanisms that are involved in those different types of learning. This violates the principle that assumptions about underlying mechanisms should be based on the results of research. Because of these problems, a mechanistic definition of learning in general is often supplemented with structural or functional definitions of different subclasses of learning (e.g., Domjan, 2010; Hall, 2003). Whereas structural definitions involve only a description of the behavior and the environment in which the behavior occurs, functional definitions imply claims about which elements in the environment are the causes of a particular behavior. Classical conditioning, for instance, is sometimes defined structurally as the change in behavior that occurs in procedures that involve the pairing of two stimuli, whereas operant conditioning refers to changes in behavior that occur when a response is paired with a stimulus (e.g., Hall, 2003). Classical conditioning has also been defined functionally as a change in behavior that is *due to* the pairing of stimuli (e.g., Catania, 1998; De Houwer, 2009; Domjan, 2010). As we discuss in more detail later on, from a functional perspective, causes are not necessarily contiguous; that is, they can occur well before the actual change in behavior. At this point in the article, however, we only want to highlight the fact that a mechanistic definition of learning is not without problems and is, therefore, often supplemented with structural or functional definitions of subclasses of learning.

The remainder of our article is organized in the following way. In the next section, we propose a functional definition of learning that might solve some of the problems of both a simple functional definition of learning and mechanistic definitions of learning. The third section of our article describes exactly how it circumvents those problems. In a fourth and final section, we examine in detail an additional advantage of functional definitions of learning—namely, the fact that they serve to promote cognitive learning research.

Learning as ontogenetic adaptation

Darwin's (1859) theory of evolution is undoubtedly one of the most important scientific insights that humankind has ever achieved. Living organisms are not static, unchangeable entities but change and evolve constantly. The driving force behind evolution is adaptation to the environment. The better an organism is adapted to the environment, the higher the probability that it can reproduce. Because certain features of an organism can be passed on from one generation to the next through reproduction, features that improve adaptation are more likely to be passed on than other features.

Evolution theory is concerned mainly with the study of phylogenetic adaptation—that is, the adaptation of a species to the environment across generations. Learning psychology, on the other hand, can be seen as the study of ontogenetic adaptation—that is, the adaptation of an individual organism to its environment during the lifetime of the individual (Skinner, 1938, 1984). In line with this idea, learning can be defined as *changes in the behavior of an organism that are the result of regularities in the environment of that organism*. From this perspective, learning research should be at the heart of psychology, in the same way as evolution theory is central to biology.

Our definition consists of three components: (1) changes in the behavior of the organism, (2) a regularity in the environment of the organism, and (3) a causal relation between the regularity in the environment and the changes in behavior of the organism. Although we realize that it is unrealistic to provide definite, generally agreed upon definitions of complex concepts such as behavior, regularity, and causality, in the following paragraphs, we hope to shed some light on how we conceptualize the three components of our definition of learning.

First, in line with the functional approach in psychology (Chiesa, 1992, 1994; Skinner, 1938), we define the term *behavior* very broadly. It encompasses every observable response that a living organism can make, regardless of whether the response is produced by the somatic nervous system (e.g., pressing a lever), the autonomic nervous system (e.g., salivation), or neural processes (e.g., electrical activity in the brain). Also, conscious thought is considered to be behavior, be it a subclass of behavior that can be observed only by the organism itself. We think of all types of behavior as responses to the environment—that is, as linked to the presence of certain stimuli in the (current or past) environment rather than as occurring randomly. A change in behavior is thus a change in the way an organism responds when it is or has been present in a certain environment. Although it is broad, our definition excludes phenomena that are situated outside the individual organism (e.g., stimuli), properties of an organism that are by definition unobservable (e.g., unconscious information processing), or properties of an organism that are not responses (e.g., the physical makeup of the organism). Whereas changes in unconscious mental processes (e.g., the formation of associations in memory) cannot qualify as instances of learning, unconscious changes in behavior (i.e., changes in behavior that the organism cannot discriminate) can qualify as instances of learning provided that an external observer (e.g., an experimenter) observes these changes.

Second, the concept of *regularity* encompasses all states in the environment of the organism that entail more than the presence of a single stimulus or behavior at a single moment in time. It can thus refer to the presence of a single stimulus or behavior at multiple moments in time, the presence of multiple stimuli or behaviors at a single moment in time (as in one-trial learning), and the presence of multiple stimuli or behaviors at multiple moments in time. Note that the behavior of an organism is also considered to be part of the environment and can thus be part of the regularities that change the behavior of the organism (e.g., pressing a lever that is followed by the delivery of food). The concept of *regularity* excludes not only the presence of a single stimulus at a single moment in time, but also other factors, such as the genetic makeup of an organism.

Third, we think of causation in functional rather than mechanistic terms (see Chiesa, 1992, 1994; Skinner, 1953). A functional relation between environment and behavior implies merely that the behavior is a function of a certain element in the environment. The element in the environment can be seen as an independent variable whose properties determine the dependent variable that is behavior. From this functional perspective, the concept of *causation* does not imply a force or mechanism by which the cause produces the effect. Therefore, unlike mechanistic causes, functional causes are not necessarily contiguous in nature; that is, they are not necessarily present at the time that the behavior changes. Note that claims about functional causes are always hypothetical in that a functional causal relation cannot be observed directly but needs to be inferred on the basis of observations and arguments.

On the basis of our definition of learning, we can specify what it means to say that learning has occurred. Such a proposition is, in essence, a hypothetical claim about the functional causes of an observed change in behavior. More specifically, it entails the hypothesis that the change is due to a regularity in the (present or past) environment, rather than to some other factor. Such hypotheses can refer to the impact of all kind of regularities on all kinds of behavior. There are no further restrictions other than those imposed by our definitions of behavior, regularity, and causality (see above). For instance, the fact that changes in behavior need to be driven by regularities in the environment (i.e., are instances of adaptation) does not imply that those changes must improve in some way the interaction with the environment (i.e., be adaptive). Moreover, as hypotheses, claims about learning are subjective in that they are formulated by an observer on the basis of the information that is available to that observer. Claims about learning are thus shaped by the learning history of the observer and can be subjected to debate.

How our functional definition circumvents the problems of other definitions

In the first section of our article, we noted that a simple functional definition of learning has been criticized as being both overly inclusive (e.g., to include changes in behavior due to a single presentation of a salient stimulus, such as a loud noise) and not inclusive enough (e.g., to exclude latent learning). Mechanistic definitions of learning, on the other hand, could be regarded as appropriate in scope (i.e., sufficiently inclusive and exclusive) but difficult to verify. Moreover, they do not suggest a straightforward way to define and differentiate between various subclasses of learning. In this section, we argue that our functional definition of learning might circumvent the problems of both a simple functional definition and mechanistic definitions. More specifically, we argue that our definition (1) is less inclusive than a simple functional definition, (2) is compatible with the phenomenon of latent learning, (3) is easier to verify than mechanistic definitions, and (4) implies a straightforward way to define and differentiate between different types of learning.

Delineating learning from other phenomena

Some have argued that a simple definition of learning as the effect of experience on behavior is too broad in that it encompasses virtually all changes in behavior (e.g., Domjan, 2010; Lachman, 1997). As we have already pointed out in the first section of our article, this problem is somewhat overstated in that even a simple functional definition excludes changes in behavior that are due to factors other than experience—for instance, the genetic makeup of the organism.[1] Nevertheless, a simple definition of learning incorrectly classifies all effects of experience on behavior as instances of learning. Our definition of learning alleviates this problem by introducing the concept of regularities in the environment. Instances in which experience produces a change in behavior but does not involve a regularity in the environment (i.e., a single stimulus that is presented at a single moment in time) do not count as instances of learning. Hence, our definition is less inclusive than a simple functional definition.

A reviewer noted that our definition might be overly restrictive and argued that definitions should merely explicate the topic of research so as to allow communication between researchers. However, to allow for effective communication, different concepts should refer to different phenomena and should, therefore, not be overly inclusive. We believe that the introduction of the concept of *regularity* in a functional definition of learning allows us to strike the right balance in terms of inclusiveness. Like a simple functional definition of learning, our definition clarifies that learning encompasses the impact of experience on behavior, but it excludes from the definition one important type of experience that is generally considered to be outside the realm of learning research (i.e., the experience of a single stimulus at a single point in time). In all other respects, our definition is at least as inclusive as a simple functional definition (see our broad definition of the concept of *behavior*).

[1] Environmental and genetic factors often interact. Take the phenomenon of imprinting in birds. A young bird will develop the song pattern that is characteristic of its species only if it hears the song of an adult member of its species during a specific limited period of time in its life. It seems clear that both genetic factors (e.g., those that determine the period of time during which the bird is receptive) and regularities in the environment (e.g., experiencing a certain song pattern) play a causal role. According to our definition of learning, phenomena such as imprinting are instances of learning because there is a causal impact of a regularity in the environment on behavior. The fact that these instances of learning occur only under very specific (and probably genetically determined) conditions does not deter from the fact that the change in behavior is an instance of learning. In fact, all instances of learning depend on the presence of certain enabling conditions. For instance, the behavior of a deaf person is unlikely to be influenced readily by regularities that involve auditory stimuli. Even the capacity to learn is determined genetically (e.g., Skinner, 1984). Hence, all learning ultimately depends on the presence of certain genetic codes. Genetic factors might also be involved in learning in other ways. Just as neural activity can change as the result of regularities in the environment, the activity or effect of genes might also be influenced by regularities in the environment. If the activity of genes in response to certain events (i.e., a genetic response) changes as the result of regularities in the environment, this change in (genetic) response would qualify as a learning effect.

Latent learning does not defy a functional definition of learning

To recapitulate, latent learning refers to a change in behavior at time 2 that is produced by an experience at an earlier time 1. As we noted earlier, it is difficult to reconcile latent learning with the idea that the experience at time 1 is the mechanistic, contiguous cause of the change in behavior at time 2. Latent learning is, however, perfectly compatible with a functional conceptualization of causation. Identifying the experience at time 1 as the functional cause of the change in behavior at time 2 does not mean that the experience at time 1 is a mechanistic, contiguous cause of the behavior at time 2. It implies only that the behavior is a function of the experience. Hence, whether there is a time delay between both is irrelevant for the claim that learning has occurred—that is, that an experience caused a change in behavior. Therefore, in contrast to what is generally assumed, latent learning is not incompatible with functional definitions of learning, including the one that we propose in this article.

Our functional definition can encompass not only the fact that latent learning involves a time gap between the experience and the change in behavior, but also the fact that an experience at time 1 produces a change in behavior at time 2, but not at time 1. Indeed, functional relations are likely to hold only when certain conditions are met. For instance, a regularity between pressing a lever and the delivery of food might lead to an increase in the frequency of leverpressing when the organism is deprived of food, but not when it has more food than it can eat. If the organism has plenty of food at the time that it presses the lever for the first time (time 1), the delivery of food upon pressing the lever might not have much of an effect on behavior. Nevertheless, a subsequent increase in the frequency of leverpressing at time 2 (e.g., when the organism is food deprived) could still be attributed to the regularity experienced at time 1. Such a functional statement does not commit itself to identifying a mechanism inside the organism that explains why the regularity did not have an immediate effect but did have a delayed effect (e.g., following a change in motivation). It only entails the hypothesis that some regularity in the environment acted as the functional cause of the change in behavior at time 2 and that this functional relation is moderated by other elements of the (present or past) environment (e.g., relative levels of food deprivation). Note that from a functional perspective, learning can be said to have taken place only after a change in behavior has been observed at least once. It makes sense to formulate a hypothesis about the functional causes of a change in behavior (and thus to claim that learning has taken place) only after this change has occurred. In this sense, a change in behavior is a necessary condition for inferring that learning has occurred. Once a change in behavior has occurred and has been attributed to a regularity in the environment, one can start exploring the variables that determine *when* the regularity influences behavior. We return to this issue in the next section.

Our functional definition of learning can be verified using experimental procedures

On the basis of the arguments that we have presented so far, we conclude that our definition of learning rivals mechanistic definitions in terms of scope. In this subsection, we argue that it is superior to mechanistic definitions in terms of the ease with which it can be verified. Both our functional definition and mechanistic definitions imply that observing a change in behavior is not sufficient for verifying the presence of learning. The two types of definitions differ with regard to the additional conditions that they require. As we noted earlier, mechanistic definitions require the demonstration of a certain change in the organism, something which is extremely difficult to achieve without specific knowledge about what this change might be and how it can be detected. Our functional definition, on the other hand, requires that a change in behavior is causally attributed to a particular regularity in the environment. Although functional causal relations cannot be observed directly, they can be inferred on the basis of experimental research. In the laboratory, functional relations can be verified by (1) manipulating the potential causal regularity while keeping constant other aspects of the environment and (2) assessing whether certain aspects of behavior change.

The following example might clarify this point. Immediately after birth, human babies show a grip reflex—that is, they automatically close their hand when the palm of the hand is stimulated. The disappearance of the grip reflex with age can be labeled as an instance of learning only if it is due to a regularity in the environment—for example, the fact that the palm of the hand of the infant was repeatedly stimulated. However, the reflex might also disappear because of spontaneous (i.e., genetically preprogrammed) changes in the brain that occur independently of regularities in the environment. In that case, the change in behavior cannot be labeled as learning. Whether the disappearance of the grip reflex is learning can, in principle, be determined by manipulating the number of times that the palm of the hand is stimulated during the lifetime of the baby. Outside the laboratory, similar levels of control over the environment are difficult, if not impossible, to achieve. Hence, some caution is needed when making claims about learning outside the laboratory.

According to a reviewer, the difficulty of identifying causally effective regularities shows that a simple functional definition without the concept of regularity is superior to our functional definition. We disagree. Even a simple functional definition implies a causal impact of some type of experience on behavior. Verifying which experience caused a change in behavior is at least as difficult as verifying which regularity caused a change in behavior. Hence, both types of definitions are faced with similar problems in terms of verifiability. More important, however, these problems are less extensive for functional definitions than for mechanistic definitions.

Different types of learning involve different types of regularities

The functional definition that we put forward in this article allows one to define and differentiate between subclasses of learning by adding information about the nature of the regularity that causes the change in behavior. Historically, learning research has dealt primarily with the effects of three types of regularities in the environment: (1) regularities in the presence of one stimulus over different moments in time, (2) regularities in the presence of two stimuli (both at one moment in time, as in one-trial learning, and across different moments in time), and (3) regularities in the presence of a behavior and a stimulus (also at one moment in time and across several moments in time). Each of these three types of regularities can have an effect on behavior and, thus, can lead to learning. We can therefore make a distinction between three types of learning depending on the type of regularity that produced the observed change in behavior.

The first type of learning concerns changes in behavior that are due to regularities in the presence of one stimulus. Such instances of learning have been referred to as *nonassociative learning*. Habituation is probably the best-known example. It refers to a decrease in the intensity of a response as the result of the repeated presentation of a stimulus. Another phenomenon in this class is sensitization, which refers to an increase in the intensity of a response that results from the repeated presentation of a stimulus (for recent reviews, see Barry, 2006; Bradley, 2009). The second type of learning concerns changes in behavior that are due to the relation between the presence of two or more stimuli. This second type of learning is typically called *classical conditioning* or *Pavlovian conditioning* (see Bouton, 2007, for a review).[2] The third type of learning that has been studied in learning research concerns changes in behavior that are due to the relation between the presence of a behavior and the presence of stimuli in the environment. Such phenomena are most often called *operant conditioning* or *instrumental conditioning* (for recent reviews, see Bouton, 2007; Pierce & Cheney, 2008).

In the same way that it can be difficult to determine whether a change in behavior is due to a regularity in the environment (and thus is an instance of learning), it can be difficult to determine which regularity in the environment is responsible for a change in behavior (and thus which type of learning has occurred). However, experimental studies in the laboratory can be designed to disentangle the impact of different

[2] This definition of classical conditioning does not encompass priming effects. Although priming procedures can also be said to involve pairs of stimuli (i.e., a prime stimulus followed by a target stimulus), priming concerns the effect of a *single* prime stimulus on the response to the target stimulus. Classical conditioning, on the other hand, concerns the effect of *pairs* of stimuli (e.g., a beep and a shock) on the response to a stimulus (e.g., a subsequent presentation of the beep).

regularities. Consider, for instance, a dog that starts salivating upon seeing a light after the light has been followed consistently by the delivery of food. In principle, the increase in salivation could be due either to the repeated delivery of food (in which case, the increase in salivation would qualify as an instance of nonassociative learning) or to the relation between the presence of the light and the presence of the food (in which case, the increase in salivation would qualify as an instance of classical conditioning). These two competing hypothetical causal attributions (i.e., competing claims about learning) can be disentangled by comparing the change in salivation when the light and food are paired with a control condition in which the light and food appear equally often but in an unpaired manner. More generally, experimental procedures allow one to manipulate certain regularities while keeping others constant and can, thus, be used to support claims about types of learning.

The functional definition of learning promotes rather than hinders cognitive learning research

Our functional definition of learning not only circumvents the problems of other definitions, but also has an important additional benefit for cognitive learning research. The cognitive approach has dominated psychology during the past 40 years or so. Importantly, cognitive psychology involves a mechanistic approach to understanding behavior in that it aims to uncover the mental mechanisms that drive behavior (Bechtel, 2008). As we noted in the first section of this article, such a mechanistic agenda at first glance seems to be incompatible with functional definitions that eschew assumptions about mechanisms. Cognitive researchers who share this belief might thus be hesitant to adopt the functional definition of learning that we put forward in this article. Recently, however, it has been argued that functional definitions might actually promote cognitive research (e.g., De Houwer, 2011). In this section, we explore whether and how our functional definition of learning could support cognitive learning research. In a first subsection, we argue that the functional definition of learning is perfectly compatible with the aims of cognitive learning research. In the next two subsections, we claim that it even strengthens a cognitive approach in two ways. First, it facilitates steady progress in the development of cognitive theories. Second, it reveals that cognitive learning research can contribute also to the functional approach within learning research. This strengthens cognitive learning research in that it widens its implications. In a final subsection, we point out that adopting a functional definition of learning also allows for the study of seemingly cognitive forms of learning, such as learning via instruction and inference.

Cognitive theories as hypotheses about how learning occurs

Defining learning as the effect of regularities in the environment on behavior reveals that learning research can address two questions. (1) *When* do the regularities lead to changes in behavior? (2) *How* do the regularities lead to changes in behavior? From this perspective, cognitive learning research deals with the *how*-question. Its aim is to specify a mechanism of mediating mental states and operations by which regularities in the environment produce changes in behavior (Bechtel, 2005; De Houwer, 2011). Cognitive learning researchers postulate that regularities in the environment can influence behavior only via the formation, transformation, and activation of mental representations within the organism. As such, mental processes are assumed to act as necessary intervening causal agents that provide contiguous causes of behavior (e.g., Dickinson, 1980; Wagner, 1981).

Different cognitive theories of learning differ with regard to assumptions about (1) the precise nature of the intervening mental representations, (2) the conditions under which they are formed, and (3) the conditions under which they influence behavior. For instance, most current theories of classical conditioning incorporate the assumption that conditioning is (1) mediated by associations in memory that (2) are formed between representations of stimuli that co-occur in a reliable manner and that (3) have a relatively direct effect on behavior (see, e.g., Bouton, 2007, for a review). Importantly, when adopting a functional definition of learning, cognitive theories can be constructed and tested on the basis of information about *when* learning occurs. The quality of a theory depends on the extent to which it can explain existing knowledge about the conditions under which learning occurs (i.e., its heuristic value) and the extent to which it makes new predictions about the conditions under which learning occurs (i.e., its predictive value). Hence, the more we know about when learning occurs, the better able we are to construct and evaluate cognitive theories about how learning occurs. In sum, our functional definition of learning clearly allows for cognitive learning research.

Functional definitions promote cognitive learning research

Functional definitions promote the development of cognitive learning theories

We now address the perhaps more contentious claim that cognitive research would benefit from adopting functional, rather than cognitive, definitions of learning. Cognitive definitions of learning are mechanistic in that they refer to a specific change in the organism—more particularly, a change in mental constructs (e.g., knowledge, representations, associations)—that can function as a contiguous cause of changes in behavior. The presence of those mental constructs is particularly difficult to verify because they are nonphysical (i.e., they represent information that in principle can be implemented in a different physical system; see Gardner, 1987). In order to study them, cognitive researchers therefore often resort to the use of behavioral proxies. A proxy is a behavioral effect whose presence and properties are thought to reflect the presence and properties of a particular mental construct. For instance, classical conditioning effects are often seen as a proxy of the formation of associations in memory. When classical conditioning is observed, it is inferred that association formation has taken place (e.g., Gawronski & Bodenhausen, 2006, p. 697).

Using proxies of mental constructs entails at least two risks (De Houwer, 2007, 2011; Eelen, 1980). Consider the practice of using classical conditioning as a proxy for association formation (e.g., Gawronski & Bodenhausen, 2006). First, it denies the possibility that the effect of stimulus pairings on behavior can be due to processes other than association formation. There is no logical basis for excluding this possibility. In fact, recently the idea was raised that classical conditioning effects are often (if not always) due to the formation and evaluation of propositions, rather than the formation of associations (e.g., De Houwer, 2009; Mitchell, De Houwer, & Lovibond, 2009). Entertaining the possibility that classical conditioning can be due to processes other than association formation has led to a number of new discoveries about the conditions under which conditioning occurs (see De Houwer, 2009, for a review). Many of these discoveries might have been missed if classical conditioning as an effect remained equated with association formation as a mental process.

The second risk of using proxies of mental constructs can also be illustrated in the context of classical conditioning research. When classical conditioning as a behavioral effect is conflated with the mental process of association formation, doubts about the merits of association formation theories could lead to doubts about the merit of research on classical conditioning. Examples of cases in which this risk has materialized can be found in the history of learning research (Eelen, 1980). Until the early 1970s, many learning researchers equated classical conditioning with a specific type of association formation process—namely, the unconscious formation of stimulus–response associations (see Brewer, 1974, pp. 27–28). During the 1960s and 1970s, research revealed very little, if any, evidence for conditioning when (human) participants are unaware of the relations between events (for recent reviews, see Lovibond & Shanks, 2002; Mitchell et al., 2009). On the basis of this evidence, Brewer (1974) wrote a highly influential chapter, the title of which summarized his main conclusion: “There is no convincing evidence for operant or classical conditioning in adult humans.” Given this conclusion, it is not surprising that many psychologists lost interest in conditioning research (Rescorla, 1988). This unfortunate evolution results from a failure to conceptually separate classical conditioning as a functional effect (which was not discredited by the findings that were reviewed by Brewer, 1974) from classical conditioning as the mental mechanism of unconsciously forming stimulus–response associations (which was discredited by the evidence reviewed by Brewer). Although we are not the first to draw attention to this conceptual error (e.g., Eelen, 1980; Rescorla, 1988), and highly sophisticated alternative theories have been developed since the early 1970s (e.g., Dickinson & Burke, 1996; Kruschke, 2001; Wagner, 1981), many psychologists explicitly or implicitly continue to think of classical conditioning as a mental process that involves the formation of associations in memory (e.g., Field, 2006; Gawronski & Bodenhausen, 2006; Mineka & Zinbarg, 2006). As has been suggested by proponents of propositional models of classical conditioning (e.g., Mitchell et al., 2009), such a view might well be wrong. It would thus be prudent to define classical conditioning merely in terms of elements in the environment without invoking any mental constructs. In that way, the fact that humans do show conditioning *effects*—and thus, that conditioning research remains valuable for understanding human behavior—can never again be challenged when ideas about the mechanism that mediates conditioning change.

More generally, the use of proxies of mental learning processes, such as association formation, is problematic because it conflates the explanandum (i.e., that which needs to be explained) with the explanans (i.e., that with which one explains) of learning psychology. Defining (different types of) learning in strictly functional terms, on the other hand, enforces a strict conceptual separation of the explanandum and explanans of cognitive learning research. The to-be-explained behavioral effects are defined only in terms of the impact of elements in the environment on behavior. No a priori assumptions are made about the mental processes that mediate these learning effects. Hence, cognitive theories of learning would no longer be restricted by a priori ideas about *how* learning might occur but only by the empirical data about *when* learning effects occur. In addition, knowledge about the conditions under which learning occurs can be accumulated independently of changes in cognitive learning theories. As such, a functional definition of learning provides guarantees for open-mindedness and stable growth in cognitive learning research. [3]

[3] The argument that functional definitions are couched in terms of the physical environment, rather than nonphysical mental constructs, does not imply that functional definitions are objective in the sense of being in line with the actual state of the environment. As we noted earlier, the functional definitions and explanations that a researcher comes up with are probably biased by the learning history of the researcher or the mental constructs that the researcher has formed. What is essential, however, is that functional definitions of learning do not entail assumptions about the mental processes and representations of the organism that reveals the change in behavior. As such, they respect the conceptual separation of the explanandum and explanans of learning research.

Functional definitions reveal the contribution of cognitive learning research to functional learning research

Defining learning in a functional manner not only optimizes cognitive explanations of learning, but also reveals that cognitive research can contribute to a functional level of explanation. Establishing the presence of learning requires evidence about the causes of changes in behavior and, therefore, provides an explanation for those changes. For instance, claiming that the disappearance of the grip reflex is an instance of habituation implies that this change in behavior is due to the repeated stimulation of the hand during the lifetime of the child. Acquiring knowledge about *when* learning occurs thus allows us to improve our understanding of behavior. In other words, functional knowledge about learning (i.e., knowledge about the environmental conditions that moderate learning) provides us with functional explanations of behavior (i.e., explanations of behavior in terms of regularities in the environment). Whereas the cognitive approach in learning psychology aims to explain learning effects (explanandum) in terms of mental constructs (explanans), the functional approach aims to explain behavior (explanandum) in terms of regularities in the environment (explanans). Learning researchers can thus strive to uncover the environmental laws of behavior—that is, accurate, unambiguous, and economical functional explanations of behavior (Skinner, 1938). Such explanations can take the form of verbal statements but can also be formalized using mathematical formula in which mathematical symbols are defined in terms of observable properties of the environment and behavior. This ambitious aim has been the focus of radical behaviorists such as Skinner (e.g., Chiesa, 1994; Skinner, 1938).[4]

Unlike most radical behaviorists, we do not believe that the functional and cognitive levels of explanation are mutually exclusive. On the contrary, both levels of explanation are mutually supportive. We already explained that progress at the functional level of explanation (i.e., information about when learning occurs) can lead to progress at the cognitive level of explanation. In a similar vein, good cognitive learning theories generate new predictions about the conditions under which learning occurs and, thus, facilitate progress at the functional level of explanation. As such, our functional definition of learning reveals a functional–cognitive framework for learning research that encompasses two mutually supportive levels of explanation (see also De Houwer, 2011). The framework does not, however, imply primacy of a particular level of explanation. Whether one considers functional or cognitive explanations as the ultimate aim of learning research depends on fundamental philosophical assumptions that go well beyond the framework itself (Hayes & Brownstein, 1986). Whichever level of explanation one prefers, progress at that level can be facilitated by progress at the other level of explanation. The functional–cognitive framework thus reconciles the two approaches that have dominated learning research since its conception. Importantly, all these benefits result from adopting our functional definition of learning.

A functional definition of learning via instruction and inference

There can be little doubt about the fact that humans often learn via instruction and inference. For instance, merely telling someone that the presentation of a light will be followed by the administration of an electric shock can induce an emotional response to the light (e.g., Cook & Harris, 1937). This change occurs even though the light and shock have never been actually experienced together. Likewise, if an observer sees someone who shows a fearful response in the presence of a particular animal, the observer could infer that the animal is dangerous and, thus, develop a fear response to the animal (e.g., Askew & Field, 2007). Behavior toward the animal changes even though the observer never had any direct contact with the animal. Because it involves language and thought, learning via instruction and inference seems to be, by definition, cognitive in nature. Moreover, it seems to fall outside of the scope of a functional definition of learning because there do not appear to be regularities in the environment of the organism (e.g., pairings of light and shock or direct contact with the animal) that might have caused the change in behavior.

In the past, some researchers claimed that learning via instruction and inference can be attributed to regularities in the environment of the organism in much the same way as other forms of learning. For instance, fear that results from

[4] Methodological behaviorism provides a third approach to the study of learning, which is sometimes not distinguished clearly from radical behaviorism (see Chiesa, 1994). In fact, the definitions of, and relationships among, different types of behaviorism are complex both historically and philosophically (e.g., Zuriff, 1985). For present purposes, however, it seems important to note the following similarities and differences among the two behaviorisms. Similar to radical behaviorism, the methodological tradition eschews any reference to a mental or representational system in explaining behavior. However, methodological behaviorism defines thought as covert speech, which could, in principle, be observed by measuring movements of the larynx during thinking (Watson, 1913). Radical behaviorists, on the other hand, consider thoughts (and feelings) to be private behavioral events that may or may not correlate with specific muscular movements; such private events are viewed as part of a behavioral system that must be explained by reference to current and past contacts with environmental regularities (e.g., Barnes, 1989; Hayes & Brownstein, 1986). Note that any functional approach can in principle entail intervening variables that are defined entirely in terms of observable elements in the environment. However, when intervening variables are given a meaning that goes beyond observable elements in the environment, they become theoretical constructs that surpass a strict functional approach (MacCorquodale & Meehl, 1948).

observing a model who reacts fearfully in the context of a particular animal can be attributed to the pairing of the neutral animal and the fearful expression of the individual (e.g., Field, 2006; Mineka & Zinbarg, 2006). Likewise, fear that results from the instruction that a light will be followed by a shock has been attributed to the pairing of the words *light* and *shock* (e.g., Field, 2006; Field & Lawson, 2008).

Although this proposal has until now remained largely unchallenged, we believe that it is insufficient to capture the complexity of learning via instruction and inference. Most important, learning via instruction and inference is likely to depend on much more than the mere presence of a particular regularity. For instance, both the sentence "a light will be followed by a shock" and the sentence "a light will not be followed by a shock" involve the pairing of the words *light* and *shock*, but their effect on behavior is very different. Likewise, observing a fearful expression of a model in the context of an unknown animal is unlikely to result in fear of the animal if the observer is told that the model was responding not to the animal but to another object (e.g., Baeyens, Vansteenwegen, De Houwer, & Crombez, 1996).

One way to deal with this criticism of existing functional definitions of learning via instruction and inference is to point out that all types of learning can depend on more than the mere experience of a particular regularity. More specifically, all types of learning can be moderated by additional regularities in the environment. The simplest example of moderated learning is perhaps sensory preconditioning (other examples include second-order conditioning and US revaluation). In sensory preconditioning studies, CS1–CS2 pairings are followed by CS2–US pairings. If the response to CS1 changes, one possible hypothesis is that the change is due to the CS1–CS2 pairings and, thus, qualifies as an instance of classical conditioning. However, the effect of the CS1–CS2 pairings is moderated by the experience of the CS2–US pairings. Without the experience of the CS2–US pairings, no change in the response to CS1 would be observed. One could thus consider sensory preconditioning effects to be instances of moderated classical conditioning.[5] Moderated learning effects are important because they demonstrate that the causal effect of regularities on behavior should always be considered in a broader context of other regularities. It also has an important adaptive value in that it allows for a fine tuning of learning itself. More specifically, moderated learning can be conceived of as "ontogenetic adaptation of learning" or "learning of learning"—that is, effects of regularities in the environment on how other regularities in the environment influence behavior. As such, moderated learning dramatically increases the flexibility with which organisms can adapt to their environment.

From this perspective, one could think of learning via instruction and inference as instances of moderated learning. If someone tells you that a light will be followed by a shock, the pairing of the words *light* and *shock* within the context of a verbal instruction influences your subsequent reaction to the light only because of a host of prior learning experiences that have endowed you with verbal abilities. These other learning experiences are much more complex than those involved in sensory preconditioning (see Hayes, Barnes-Holmes, & Roche, 2001, for a theory about what those learning experiences might look like), but in both cases, the effect of a particular regularity (i.e., the pairing of the words *light* and *shock* in a verbal instruction or the paired presentation of the stimuli CS1 and CS2) is moderated by other learning experiences.[6] Likewise, the effect of the pairing of a novel animal and a negative facial expression could depend on moderating experiences via which the target individual has learned that negative facial expressions are typically evoked by the negative properties of the object that is being looked at. The fact that it is not yet certain which other experiences allow for learning via instruction and inference should not stop us from defining these effects as instances of moderated learning. On the contrary, such functional definitions highlight the challenge of identifying those other regularities (see Hayes et al., 2001). Moreover, it allows research on learning via instruction and inference to benefit from the advantages of the functional–cognitive approach. Hence, conceiving of learning via instruction and inferences in functional terms as instances of moderated learning not only is possible, but also can convey also benefits.

Concluding comments

Given the central role of the concept of *learning* in psychology, it would be good if researchers could reach some level of consensus about what this concept actually entails. In this article, we put forward a detailed functional definition of learning. Not only does it solve problems related to other definitions of learning, but also it is compatible with and has advantages for cognitive learning psychology.

Regardless of whether researchers will rally round the specific definition that we put forward, we hope that our

[5] Learning can be moderated not only by regularities in the environment, but also by other factors such as the genetic makeup of the organism. Whereas the expression *moderation of learning* could be used to refer to all cases in which learning is moderated, the use of the term *moderated learning* could be restricted to those cases in which learning is moderated by regularities in the environment of the organism.

[6] Note, however, that also seemingly simple types of learning effects such as sensory preconditioning might—at least in humans—be moderated by the prior acquisition of verbal abilities. In fact, some have argued that classical and operant conditioning in humans always depends on skills similar to those that underlie verbal behavior (e.g., Hayes et al., 2001).

conceptual work furthers the debate about the definition of learning. There are several potential contributions that go beyond the specific definition that we put forward. First, we hope to have made explicit the important distinction between functional and mechanistic definitions of learning. Using the term *learning* without specifying whether one refers to learning as a functional effect or as a mechanistic process is bound to lead to confusion. Moreover, distinguishing between learning as an effect and learning as a mechanism reveals the explanandum and explanans of the functional and cognitive approaches in learning research, as well as the interdependency of these approaches.

Second, we recommend using the term *learning* exclusively at the functional level. An alternative approach is to define learning as an explanatory mental mechanism and invent a new term to refer to learning as a to-be-explained functional effect. However, as we argued above, defining learning in terms of mental mechanisms has several disadvantages (e.g., difficult to verify, which leads to the use of proxies). Defining learning at the functional level, on the other hand, promotes a strict separation of the explanans and explanandum of learning research and, thus, enhances learning research in the long run. We realize, however, that there are also downsides to adopting a functional definition of learning. Most important, cognitive researchers will have to let go of their habitual conceptualization of learning as a mental mechanism. Changing such habits will take time and effort and might thus meet resistance. However, it is our conviction that such a change will produce significant benefits for learning research in the long run.

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