

Formal Definitions of “Primary” and “Secondary” Reinforcers Promote More Efficient Animal Training

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Abstract

There is widespread misunderstanding regarding primary versus secondary reinforcers within the animal training community. In this article, I will clarify the definitions: primary reinforcers being “independent of their correlation with other reinforcers,” and secondary reinforcers as “initially neutral and dependent on their association with other reinforcers.” Secondary reinforcers lose their effectiveness if that correlation, or pairing, is discontinued. By returning to these formal scientific definitions, secondary reinforcers used by animal trainers would be essentially limited to clickers, whistles, or other marker signals. For trainers currently operating under alternative interpretations of this definition, returning to well-established formal definitions would lead to more efficient training in terms of speed and persistence of conditioning, a larger selection of reinforcers in different situations, avoiding prospective satiation or extinction of available reinforcers, and a better understanding of potential distractors as well as unwanted behavior.

There are different schools of thought within animal training communities with respect to what

constitutes primary and secondary reinforcers. Several training terms have multiple—and divergent—interpretations in various training circles, and many training procedures are carried out in different ways by different trainers. This variation likely reflects the expansion of the animal training industry in the last 70 years, and the diversity in educational backgrounds and theoretical orientations. Practical training techniques have evolved in the dog training community, zoos, and aquaria, sometimes with little support from basic science, resulting in a variety of definitions and practices. The art of training has evolved under a variety of contingencies.

When defining primary and secondary reinforcers, some contemporary animal trainers have strayed from well-established formal scientific definitions. While the deviation may be considered minor, the resulting ramifications may potentially have a major impact on training efficacy, and the prevention and resolution of problem behavior. In this article, I elucidate the various ways that this deviation could be problematic in animal training. To facilitate the discussion below, I term trainers adhering to the well-established scientific formal definition (see Chance, 1998) “formal trainers,” and trainers advocating the deviation “alternative trainers.”

Formal Definition and Alternative Interpretation

Stimuli that will effectively reinforce behaviors when presented contingent upon the behavior, and for which no previous conditioning history exists, are called unconditioned positive reinforcers, unconditioned added reinforcers, or primary reinforcers. They are not dependent on a correlation, or pairing, with other established reinforcers. There are a large number of stimuli that can potentially function as primary reinforcers (table 1), at least for some animals some of the time.

Table 1. Potential primary positive reinforcers according to the formal definition: resources or stimuli that some organisms are innately willing to work for to gain access to without prior conditioning to other reinforcers. Species

differences, individual preferences and current motivational states will determine whether or not a specific stimulus is a functional reinforcer at any particular time (Laraway et al., 2003; Schneider, 2012).

Type of primary reinforcer	Species example	Reference
Food	Rats	Skinner (1938)
Drink	Pigeons	Jenkins & Moore (1973)
Play opportunities	Raccoons	Davis (1984)
Companionship / petting	Dogs	Feuerbacher & Wynne (2015)
Attention / approval	Humans	Gewitz & Baer (1958)
Reproductive opportunities	Rats	Everitt et al. (1987)
Aggressive opportunities	Fish	Hogan (1967)
Sensory stimulation (auditory, visual, olfactory, tactile, gustatory)	Sparrows, mice, dogs, etc.	Schneider (2012)
Shelter	Pythons	Stone et al. (2000)
Favorite locations and activities	Primates	Premack (1959)
Control	Humans	Finkelstein & Ramey (1977)
Variety	Primates	Hollerman & Schultz (1998)
Learning	Humans	Biederman & Vessel (2006)
Brain stimulation	Rats	Pliskoff et al. (1965)
Drugs (e.g., cocaine)	Mice	George et al. (1991)

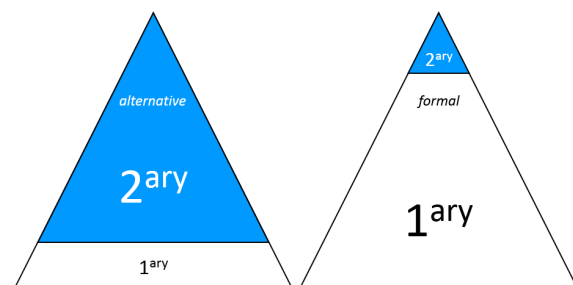
Secondary reinforcers, in turn, are “dependent on their association with other reinforcers” (See e.g., Chance, 1998). Such stimuli are initially neutral with respect to the response in question, and become conditioned when paired with unconditioned stimuli or already established conditioned stimuli (c.f. Holland, 1992). Thus, secondary reinforcers take on the reinforcing properties of the primary reinforcer with which they were paired (Feng et al., 2016), and, importantly, lose their reinforcing properties if at least occasional pairing with the unconditioned stimuli is discontinued. In contemporary animal training, secondary reinforcers might be the sound of a clicker or a whistle, or moving one’s hand towards a food pouch.

However, some animal trainers, particularly those within the marine mammal training community, misinterpret the distinction between primary and secondary reinforcers. To the best of my understanding, alternative trainers typically misconstrue primary reinforcers as only those stimuli argued to be essential for basic survival. This opens up for some subjective interpretation; some alternative dolphin trainers consider a fish a primary reinforcer, but not consumables other than fish. Other alternative trainers will consider all types of food primary reinforcers but not play, gentle touch or praise.

In other words, rather than classifying stimuli as secondary reinforcers based on whether they were previously neutral, if they take on the reinforcing properties of the stimulus with which they were paired, or lose their effectiveness if the pairing is discontinued, alternative trainers seemingly classify secondary reinforcers based on whether they are subjectively deemed to be essential for survival or not. They then establish stimuli judged to be non-essential as secondary reinforcers by an explicit pairing procedure (e.g. play-treat, touch-treat, or praise-treat).

Thus, interpretation of the terminology will have a large effect on the relative distribution of “primary” and “secondary” reinforcers (Figure 1).

Figure 1. The relative distribution of potential primary and secondary reinforcers for alternative and formal trainers. Alternative trainers only consider stimuli essential for survival to be primary reinforcers; most other stimuli are conditioned and then regarded as secondary reinforcers, regardless of whether they were initially neutral or not (typically toys, petting, praise etc.). Formal trainers consider all unconditioned stimuli that may effectively reinforce behaviour primary reinforcers (Table 1). Secondary reinforcers are stimuli which were previously neutral and have been conditioned to predict the delivery of a primary reinforcer (e.g., the sound of a clicker).



Secondary reinforcers have two uses in contemporary animal training. First, they may be used as Keep-Going Signals (KGSs) during a behavior requiring duration (Pryor, 1999), such as remaining immobile during the time required to take a blood sample. As such, KGSs signal that the ongoing behavior is correct and will eventually lead to primary reinforcement.

Second, secondary reinforcers are used as “event markers” (Feng et al., 2016). Typically, a clicker or a whistle will be sounded to pinpoint a criterion or target behavior, or terminate a long-duration behavior, and will typically be immediately followed by a treat or some other reinforcer.

In the case of their use as event markers, secondary reinforcers develop properties both as a reinforcer, as well as a discriminative stimulus. This dual nature of the secondary reinforcer will likely influence training outcome, as explained below (Figure 2). Indeed, some of the early experiments found that after an animal had been trained to exhibit a response following the onset of a stimulus (illustrating discriminated responding), that stimulus could be used to strengthen other responses preceding its onset (illustrating a reinforcing effect)(Wyckoff, 1959). In the early days, a lot of effort went into investigating how the secondary reinforcing effects of a stimulus were related to the strength of that stimulus as a cue (e.g., Schoenfeld et al., 1950). A key feature of secondary reinforcement, discussed in the scientific community many years ago, is this dual nature of predicting the availability of primary reinforcers, (an antecedent effect) as well as reinforcing preceding operant responses (a postcedent effect)(summarized in e.g., Wyckoff, 1959). It seems that this discussion has waned from the scientific community, but was raised at a recent international training conference (Bartlett, 2017).

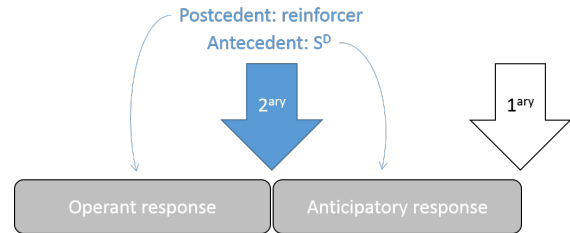


Figure 2. Secondary reinforcers have both postcedent properties, reinforcing the preceding operant response class, as well as antecedent properties, being a discriminative stimulus for behaviours yet to occur. Anticipatory responses, covert or overt, occurring in the interval between the secondary reinforcer and the delivery of the primary reinforcer, will likely influence training outcome.

As will be discussed below, it seems that many alternative animal trainers focus primarily on the reinforcing properties of their secondary reinforcers, and overlook the antecedent facet. This may be, in part, because they’ve deviated from the original formal definition. In keeping with this alternative interpretation, they condition certain stimuli and call them “secondary reinforcers”—regardless of whether conditioning is required. Thus, they don’t seem to consider that these stimuli may also have innately reinforcing properties.

Let’s take the example of using playing as a reinforcer for an animal. For the formal trainer, playing can be used as a primary reinforcer from the outset, provided that the trainer is familiar with the types of play opportunities that are reinforcing to that particular animal. For the alternative trainer, playing is typically conditioned before being used during formal training: play-treat, play-treat, play-treat.

Object play and social play have been shown to reliably reinforce behavior without this explicit pairing procedure (indeed in one experiment, a raccoon no longer reliably accepted food as a reinforcer) (Davis, 1984). Thus, there are two categories of questions to be asked with regards to the alternative conditioning procedure. What happens to “play” as it acquires properties of a conditioned reinforcer in addition to already having properties as a primary reinforcer? Secondly, how does the alternative trainer use “play” as a reinforcer henceforth?

Below I will explain why I believe that adhering to formal definitions would help trainers explain and control behavior more efficiently, and communicate more effectively with other trainers; I expect inexperienced formal trainers will be more efficient in their training than novice alternative trainers.

Outcomes of using alternative versus formal approaches.

Relationships and Reinforcers

The main reason why many alternative animal trainers go through the procedure of actively pairing, for example, tactile reinforcers with food, is to ensure that the animal will accept touch as a reinforcer by that person. Some common physical human–animal interactions may be aversive for the animal, at least if initiated by a stranger, as shown in a study on dogs by Kuhne and colleagues (2014). Indeed, many animals will not accept touch from an unknown person, and may show fearful or aggressive behavior. The formal trainer thus risks overestimating the likelihood that a particular stimulus, such as touch, is a functional primary reinforcer when delivered from that person to that animal.

It is likely that the risk of the animal not accepting a potential primary reinforcer would be increased if there are interfering competing contingencies, for instance fear of novelty or unknown persons. Once the initial fearful response has subsided, chances are increased that the no longer novel stimulus would positively reinforce behavior. The conditioning of alternative secondary reinforcers, such as touch, can thus be construed as a counter-conditioning procedure geared to prevent or eliminate fear. Is this pairing procedure necessary, or would respondent extinction suffice? Gentle touch may not be a functional reinforcer when delivered from a stranger, but may be a reinforcer when delivered by a familiar person without the explicit pairing procedure. This has, to my knowledge, not been systematically assessed.

Strength of Conditioning

Using the alternative procedure to establish conditioned stimuli (CS) involves pairing a

potentially large number of diverse stimuli (e.g., play, tactile reinforcement, clapping, etc.) with food. In laboratory studies, it has been shown that variable CSs produce less robust conditioning than unchanging CSs (e.g., Kirkpatrick, 2014). Additionally, if play or tactile stimulation is used outside of this explicit pairing procedure, such interactions may be subject to latent inhibition, also reducing the degree of conditioning (Lubow, 1973). Taken together, it is plausible that conditioning playing as a secondary reinforcer paired with food is rather ineffective unless novel toys and novel treats are used, and in a consistent manner. Indeed, it might be that the reason why the animal starts to play vigorously and seek the trainer's company has nothing to do with previous conditioning to food, but the inherently reinforcing properties of play. Over-reliance on the pairing procedure (e.g., tactile interaction paired with food) may be superstitious behavior on the trainer's part. Since conditioning occurs best when stimuli are novel and highly stereotypic, we may expect alternative conditioning procedures paired with food (play–treat/clap–treat/pet–treat/click–treat) to be less efficient than formal conditioning procedures paired with food (click–treat/click–treat/click–treat/click–treat). Thus, the clicker, as event marker, may be less effectively conditioned for alternative trainers than for formal trainers.

Secondary Reinforcers as Event Markers and Antecedents

In alternative training, stimuli that are innately reinforcing (e.g., playing), rather than neutral, are deliberately paired with food. How does this impact their effectiveness when delivered later, during actual training? Is the animal responding to the unconditioned or the conditioned properties of the alternative secondary reinforcer, to the postcedent or the antecedent (Figure 2)? Does it matter?

Different brain areas are involved in processing secondary positive reinforcers than in the processing of primary positive reinforcers (O'Doherty et al., 2002). Secondary reinforcers predict the imminent arrival of a primary reinforcer, and spark a dopamine cascade in

central parts of the brain (Panksepp, 1998, Schultz, 1998)—the covert anticipatory reaction in Figure 1. In contrast, there is no dopamine surge above baseline when the animal receives the primary reinforcer (Schultz, 1998). To my knowledge, the effect of the combination of innately reinforcing and conditioned properties in reinforcers (as in most alternative secondary reinforcers) has not been systematically studied.

Secondary reinforcement for the formal trainer typically consists of an event marker such as the sound of a clicker, established by having been paired with a primary reinforcer. Typically, the trainer clicks during or following the criterion behavior, and then follows up with one or several primary reinforcers (Table 1), such as a short play opportunity. How does an alternative trainer distinguish between the clicker and other alternative secondary reinforcers? Some novice alternative trainers may assume that any “secondary reinforcer,” including for instance praise, may be used interchangeably—replacing the click. However, play followed by petting consists of two primary reinforcers in succession, rather than one secondary and one primary: this order of events would impact brain chemistry, and thus covert behavior, differently. If alternative secondary reinforcers contain innately reinforcing properties per se, it is difficult to know whether the animal responds to the conditioned or unconditioned facet of that reinforcer. This may seem like hair splitting, but is important, as brain chemistry, overt behavior and conditioning could be very differently impacted (Arias-Carrión & Pöppel, 2007).

Alternative trainers may use event markers and their alternative secondary reinforcers interchangeably and thus stimulate dopamine release less effectively. This in turn might reduce learning speed, elation, and retention, three desirable consequences from activation of specific dopamine neurons in the amygdalae (Langbein et al., 2007; Pryor, 2009; Smith & Davis, 2008).

Overreliance on explicit pairing procedures

Supposing that at least some novice trainers, whether formal or alternative, assume that secondary reinforcers are always established

through an explicit pairing procedure carried out by the trainer (e.g., click-treat versus play-treat); this would affect the trainer’s position regarding how many potential reinforcers are made available. It is thus plausible that a novice trainer may not consider using secondary reinforcers that have not been explicitly established by that person with that animal. For the alternative trainer, play or touch would thus not be considered unless the pairing procedure had occurred. An alternative trainer would thus initially recognize a smaller number of available reinforcers to choose from, and satiation may end the training session sooner for the alternative trainer training a novice animal.

Assuming secondary reinforcers are inferior

The nomenclature itself suggests that secondary reinforcers might be interpreted as less important than primary reinforcers. The novice trainer might thus make training decisions based on the assumption that secondary reinforcers are less effective than primary reinforcers. For alternative trainers, there will only be a handful of effective reinforcers available (food, drink), others (e.g., play), would be considered ineffective. Alternative trainers might thus be less inclined to use play than food as reinforcers.

For formal trainers, most reinforcers are considered primary; no a priori distinction will be made as to the reinforcing properties of, for example, food versus play. Alternative trainers might therefore potentially recognize fewer effective reinforcers for a given situation. However, the effectiveness of any given primary reinforcer, whether seen from the formal or alternative perspective, remain conditional based on motivating operations operative at the time (Laraway et al., 2003).

Jackpot options

Variety is reinforcing (Hollerman & Schultz, 1998), and is typically used by both formal and alternative trainers. However, jackpots are typically selected from among primary reinforcers—perhaps due to beliefs about effectiveness mentioned above.

When choosing jackpots, alternative trainers have a reduced option compared to formal trainers.

Satiation and respondent extinction

Reinforcer potency (i.e., effectiveness at any given time) will decline differently depending on which training school to which you adhere. For the formal trainer, secondary reinforcers will undergo respondent extinction if the secondary reinforcer is allowed to occur too many times without the primary reinforcer following it (e.g., Clayton & Savin, 1960), whereas primary reinforcers may momentarily lose their reinforcing properties through other means, such as satiation (an abolishing operation). For the alternative trainer, this distinction may get blurred, as some alternative secondary reinforcers, such as petting, may retain their reinforcing properties even in the continued absence of follow-up tidbits, whereas the sound of the clicker will not. Vice versa, the clicker will not satiate no matter how many times it is sounded in one training session, as long as it is followed by a primary reinforcer, but petting may. However, the alternative trainer may consider petting and clicking to be equivalent, since they identify them both as secondary reinforcers, and establish them through the same procedure. The alternative trainer may thus inadvertently risk satiating the subject with respect to one type of secondary reinforcer, and respondently extinguishing responses maintained by another secondary reinforcer. Formal trainers will find it easier to make the distinction between reinforcers that stop working because of satiation or respondent extinction.

Additionally, novice trainers may keep offering the same primary reinforcer beyond satiation, oblivious to the fact that it is no longer functioning as a reinforcer. During initial training, before conditioning any secondary reinforcers, alternative trainers would be at greater risk of doing this since their choice is more limited.

Distractors in the environment

Trainers would potentially differ in how aware they are of other reinforcers available in the environment that may compete for the animal's

attention during training. Arranging the environment to limit distractions (concurrent competing contingencies) is a huge part of preparing for a training session. An alternative trainer may not consider the potential implications of whether the environmental arrangement includes competing contingencies of various kinds due to the factors discussed above. An inexperienced alternative trainer may have a weaker understanding of potential distractors interfering with training than a novice formal trainer.

Understanding Unwanted Behaviour

Animals are conditioned from natural consequences occurring in the environment, and may start exhibiting non-criterion behaviors as a result. By recognizing primary reinforcers other than food, water, air, and sex (Table 1), one may better analyze situations involving unwanted behaviours and the contingencies of which they are components. If trainers consider only food, water, and air as primary reinforcers, they may believe that there is just a small number of reinforcers available, especially if they adhere to some of the other misconceptions listed above. Alternative trainers would thus be expected to have more difficulties identifying obscure reinforcers that maintain problem behavior.

Tuning in with the Scientific Community

Scientific studies have found that primary and secondary reinforcers are processed in different parts of the brain and through distinct neural mechanisms (Beck et al., 2010). However, different primary reinforcers (e.g., food, sex) may also be processed in different parts of the brain (Sescousse et al., 2013), thus supporting the formal perspective on reinforcers as opposed to the alternative. So, alternative trainers are not in alignment with the experimental scientific community and may thus misinterpret scientific findings.

Conclusion and Recommendation

I found ten lines of argument in favor of the formal approach and one in favor of the alternative approach to using secondary reinforcers. My suggestion is thus to teach the

formal definitions to novice trainers but add the cautionary tale that a trainer should never make assumptions that a certain stimulus is actually a functional positive reinforcer when delivered from that person to a particular animal. Simply observing the animal may be one way of finding out: is the stimulus in question a reliable reinforcer or not? Does the subject exhibit behaviors that function to enhance access to it or not? In case of doubt, pairing the stimulus to a known primary reinforcer may be one solution to reduce the risk of frustration-induced or fear-induced aggressive behavior. The latter may occur if one uses, for example, attention and petting as putative reinforcers under circumstances in which these are not in fact effective reinforcers, and indeed may elicit aversive emotional reactions (particularly if delivered by a stranger), causing aversive arousal that disrupts continued training.

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