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# Hedonics and the "Selective Associations" Biological Constraint on Learning

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Research concerned with visual dominance in appetitive and auditory dominance in aversive learning situations (selective associations) is reviewed. The present analysis stresses that the dominant sensory modality of stimulus control is determined by the relative affective valence acquired by a compound auditory-visual stimulus through reinforcement contingencies, rather than by whether the primary reinforcer is appetitive or aversive. For example, take two groups of rats or pigeons on exactly the same shock-avoidance contingency in a tone-light compound (TL), but with different contingencies when the compound is absent ($\acute{T}\,\acute{L}$). Responding came predominantly under (1) auditory control when conditions in TL were hedonically negative relative to those in $\acute{T}\,\acute{L}$, and (2) visual control when conditions in $\acute{T}\,\acute{L}$ made TL relatively positive. Selective associations here are a product of the relative hedonic state, positive or negative, established to the auditory-visual compound. Therefore, this constraint reflects a high level of functioning by a hedonic comparator -- with TL's hedonic value contextually determined by the totality of the events encountered, and reinforcement contingencies, operating in its world. The physical particulars of the reinforcer in TL here, shock avoidance, clearly were not responsible for the hedonic psychological state TL produced. Weiss, Panlilio, and Schindler (1993a, 1993b) went on to show that these proclivities can be (1) reversed, and (2) overcome by a blocking design when the biologically-contingency-disadvantaged stimulus is first pretrained on its own. Relating the "hedonic model" to evolution is speculative. But, the hedonic model is scientifically integrative by relating this biological constraint to a variety of phenomena that involve incentive-motivational states. These include choice behavior, conditioned preference, behavioral contrast and appetitive-aversive interactions.

The study of conditioning and learning is concerned with the associative processes underlying learned modifications of behavior. In classical conditioning, these modifications are produced by contingencies arranged between a stimulus and an event (e.g., food or shock) that is independent of the subject's behavior. In operant learning they are produced by contingencies arranged between a response and an outcome (e.g., food or avoidance of an aversive event). Traditional behavior theory concentrated on discovering general laws of learning where stimuli, responses and reinforcers might be viewed generically, with different instances within any class of events interchangeable. This rather simplistic equipotentiality assumption of general-process learning theory was brought into question by findings demonstrating biological constraints on learning and the associability of various events (Garcia, McGowan, & Green, 1972; Seligman & Hagar, 1972; Shettleworth, 1972a; Foree & LoLordo 1973,

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Hinde & Stevenson-Hinde, 1973; Schindler & Weiss, 1982, Domjan, 1983; Weiss, Panlilio, & Schindler, 1993a, 1993b).

One of the early examples of a biological constraint on instrumental learning was reported by Breland and Breland (1961) who showed that raccoons could only be taught to drop tokens into a slot for positive reinforcement (food) with extreme difficulty, if at all. Innate patterns of behavior seemed to supersede the contingencies of reinforcement imposed by the trainer. Does this mean that the empirical law of effect (Thorndike, 1911) should be abandoned? Not necessarily.

If more than the experimenter defined aspects of their situation are considered (e.g., dropping a token into slot for food), what the Brelands called "*isbehavior* (i.e., not acting in accordance with their programmed reinforcement contingency) can be explained in terms of stimulus-reinforcer consequences relevant to obtaining and consuming food (Timberlake, Wahl, & King, 1982; Killeen, 2014). That is, the raccoon's behavior is consistent with generally applicable, if more complex, general learning principles, but the "...influence ... of...the conditioned motivational state in which the instrumental conditioning was conducted and the motivational state that was conditioned by presentations of the reinforcer must be considered" (Domjan, 1983, p. 264). From this perspective, *misbehavior* and other apparent biological constraints on learning have strengthened general-process theory by encouraging it to deal functionally with the complete learning situation. Generalizations thus developed are concerned with more detailed features of a learning situation, rather than the simplistic interchangeability of cues, responses and reinforcers (Domjan, 1983). This article will (1) review the selective association literature, (2) and present a research program of the authors and their collaborator Charles Schindler which related that biological constraint to general integrative learning principles.

LoLordo (1979) provided an empirical criterion for the existence of selective associations. That criterion came in the form of an identifiable stimulus-reinforcer interaction when a set of stimuli has been given equal opportunity to control a response, but the reinforcement contingencies determine which stimulus is most effective. Garcia and Koelling (1966) were among the first investigators to demonstrate this phenomenon. Their compound stimulus was *bright-noisy-tasty* water. In one group of rats ingestion of this water was followed by sickness produced by x-radiation or an injection of lithium chloride. The other group was shocked after drinking. Subsequent to this training, a stimulus-element test wherein the flavored water and the auditory+visual stimuli were presented separately revealed that the animals associated sickness with the flavor of the water and electric shock with the visual+auditory stimuli. Garcia and Koelling (1966) called this phenomenon *cue-to-consequence specificity*.

Although taste aversion learning has many qualitative similarities with more traditional learning situations (Mackintosh, 1974), its rapidity (one-trial) with backward-pairing and long-delay learning easily obtained (Garcia et al., 1972) do distinguish it from traditional learning situations using exteroceptive stimuli in food or shock situations. For this reason, the current article concerns itself principally with those studies of selective associations that employed more traditional operant and classical conditioning learning paradigms with audio-visual compound stimuli.

Foree and LoLordo (1973) investigated selective associations within a discriminated-operant paradigm. Different groups of food deprived pigeons were trained to depress a foot treadle in the presence of a five-second compound stimulus consisting of a 440-Hz tone and a red houselight. In one group (appetitive) this produced grain that was signaled by hopper operation and illumination of the hopper access area. For the other group (aversive) pressing the treadle avoided electric shock. After the pigeons were effectively avoiding shock or earning food in the tone-light compound, the tone and the light were presented separately on a stimulus-element test. Following appetitive training the red light exerted strong control over treadle pressing while few responses were emitted during the tone. In comparison, after training in shock-avoidance the tone controlled more responding than the light. This *stimulus-reinforcer interaction* is plotted in the right frame of Figure 1.

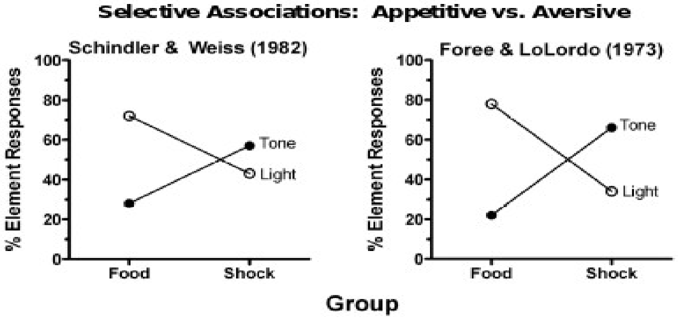


***Figure 1.*** Left frame. On a stimulus-element test, percent of total-element responses emitted during the tone and during the light by discrimination- trained rats that had earned food or avoided-shock on free-operant schedules during tone-plus-light (TL) while responding had no consequences (extinction) when TL was absent ($\acute{T}\acute{L}$; Schindler & Weiss, 1982). Right frame: Same measure for Foree-and-LoLordo's (1973) discrete-trial operant-trained pigeons. These percentages are calculated by dividing the number of responses emitted by a subject to the tone and to the light elements on its stimulus-element test by its total responses emitted to the tone *and* to the light elements and then multiplying that resultant by 100. For example, a subject's percent responses in tone = [(100 x its responses in tone)/(its responses in tone + its responses in light)]. Percentages were calculated for each subject for its tone element and its light element. The points in this and the other stimulus-element test figures presented in this article represent the mean of these individual-subject calculations. This measure would be 50% if the number of responses during the light and the tone test elements were equal. Adapted from Weiss et al. (1993a).

Schindler and Weiss (1982) tested the generality of this phenomenon over species with rats trained on free-operant contingencies. In a tone-plus-light (TL) compound their rats were taught to either (1) earn food, signaled by a feeder click upon delivery, on an variable-interval (VI) intermittent-reinforcement schedule or, (2) to postpone shock on a free-operant avoidance schedule (FOA) (Sidman, 1953). In the absence of the tone-plus-light compound $\acute{T}\acute{L}$no contingency operated [extinction (EXT)] on either two-component multiple schedule. Therefore, for their food-trained rats $\acute{T}\acute{L}$ was food-free and for their shock-trained rats it was shock-free (safe). As should be clear, on a multiple (mult) schedule different contingencies are effective when different stimuli, here TL and $\acute{T}\acute{L}$ are present. The schedule operating in (1) can be represented as mult VI EXT and that operating in (2) above as mult FOA EXT.

When a rat was responding at least ten times as rapidly in TL as its absence, Schindler and Weiss (1982) administered a stimulus-element test. On that test, a rat was presented the tone, the light and TL multiple times in a block-randomized design. This test was performed in extinction. That was to preclude non-associative activities/processes related to food and its ingestion or to shock from interfering with the expression of the associative properties established to TL in training. The results of this test are shown in the left frame of Figure 1. Consistent with Foree and LoLordo’s (1973) findings with pigeons, for their food-trained rats the light element controlled more responding than the tone element while the reverse was observed in the group of rats trained to avoid shock in TL.

There is ample evidence that the stimulus-reinforcer interactions reported by Foree and LoLordo (1973) and Schindler and Weiss (1982) were associative and not a product of sensitization or pseudo conditioning. The stimulus-reinforcer interaction was still revealed when Schindler and Weiss (1982, Exp. 3) incorporated variations of the experimental design proposed by Rescorla and Holland (1976) to control for sensitization and pseudo conditioning. Schindler and Weiss (1982, Exp. 3) presented food as well as shock in different schedule components during the same session, but only one event was associated with the tone-light compound. In addition, the stimulus-reinforcer interaction observed by Foree and LoLordo (1973) was later replicated in a classical conditioning paradigm that included two truly-random control groups that received uncorrelated presentations of the CS and either food or shock (Shapiro, Jacobs, & LoLordo, 1980). Their controls showed no selective associations.

There is little doubt that an important basic associative attentional dynamic is operating here that generalizes over species, laboratories (and therefore different tone-light compounds) plus conditioning paradigms. In addition, Figure 2 shows that selective associations can also be produced when cocaine self-administration rather than food was the positive reinforcer (Weiss, Kearns, Cohn, Schindler, & Panlilio, 2005). Nevertheless, the question remains whether this selective association is determined by class of reinforcer — appetitive or aversive — or some other process operating in these situations.

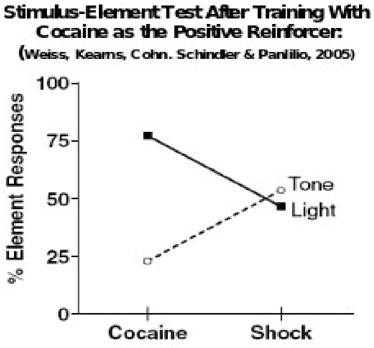


***Figure 2.*** The percentage of total stimulus-element responses emitted in tone (open circles) and in light (filled squares) by rats trained to self-administer Cocaine in TL and rats trained to avoid shock in TL. For both groups, the absence of TL was associated with extinction. See Figure 1 caption for explanation of how these percentages were calculated. From Weiss et al., 2005.)

For example, there is an important confound in the Foree and LoLordo (1973) as well as the Schindler and Weiss (1982) experiments. In both, class of reinforcer, appetitive (food) versus aversive (shock), is confounded (covaries) with the hedonic state, positive versus negative, respectively, conditioned to the TL compound stimulus. This is the case because when the rats or pigeons were working for food during TL they would be in a preferred condition compared to the nonreinforcement associated with the absence of these stimuli (Holtz, Azrin, & Ayllon, 1963). In comparison, TL would have been a non-preferred condition, compared to shock-free$\acute{T}\acute{L}$, when TL was associated with shock avoidance (LoLordo, 1969; Verhave, 1962). Therefore, in these studies reporting stimulus-reinforcer interactions in the discrete-trial and free-operant situations described above, food and shock were confounded with resulting hedonic state, positive or negative, respectively — and thus the-component preference that would have developed on the discriminative operant baselines.

A similar confounding was also present when selective associations were demonstrated in classical conditioning (Jacobs & LoLordo, 1977) with the CS being positive when followed by food and negative when followed by shock. Therefore, it is indeterminate whether in these instances the selective associations are due to type of reinforcer, food vs. shock, or the hedonic states the TL compound would induce after being associated with food or shock in the two groups. There is a class-of-reinforcer by conditioned-hedonic-state confounding here.

From the results presented above, as well as those of Shapiro et al. (1980) one could contend that when TL signals an hedonically preferred condition, the light will be selectively attended to, and when it signals a non-preferred condition the tone will be attended to. Clearly, in this analysis, the selective association is related to a contingency-generated psychological state rather than food or shock associated situations per-se. A series of experiments supporting this contention was reported by Jacobs and LoLordo (1977, 1980) who produced selective associations by presenting a compound stimulus in different relations to the same reinforcer.

Jacobs and LoLordo (1980) compared the effectiveness of auditory and visual warning and safety signals. After training rats to respond to avoid shock on a free-operant baseline, auditory and visual stimuli were classically paired with the onset or termination of shock [i.e., they were made warning and safety signals, respectively (Jacobs & LoLordo, 1980)] or they were placed in these relations to shock using a discrete trials avoidance schedule with a new response which either terminated the warning stimulus or produced the safety stimulus (Jacobs & LoLordo, 1977). The rats were then returned to the free-operant avoidance baseline and the auditory and visual stimuli were presented in a transfer-of-control procedure.

As a warning stimulus, only the onset of noise increased avoidance responding. However, the onset of light, the offset of light, and the offset of noise (but not the onset of noise) decreased avoidance responding when they had been paired with safety from shock. This indicated that only the auditory stimulus was effective when paired with shock (a non-preferred condition), and only the non-auditory stimuli were effective when associated with safety (a preferred condition). Stimuli were differentially effective when placed in different relations to the same event, shock.

The hedonic model of selective associations was formulated on the basis of the confound between class of reinforcer and conditioned component preference that would have existed in the Foree and LoLordo (1973), Shapiro et al. (1980) and Schindler and Weiss (1982) studies. The Jacobs and LoLordo (1977, 1980) experiments showing the formation of selective associations to warning and safety signals**,** both maintained by their relationship to the same event, shock, were consistent with this hypothesis. Weiss et al. (1993a, 1993b) were the first to formally propose, and directly test, that selective associations could be a product of conditioned hedonic states. Their studies were designed to break the confound between hedonically positive (preferred) and hedonically negative (non-preferred) audio-visual conditions created by the reinforcement contingencies operating therein with class of reinforcer – appetitive and aversive, respectively.

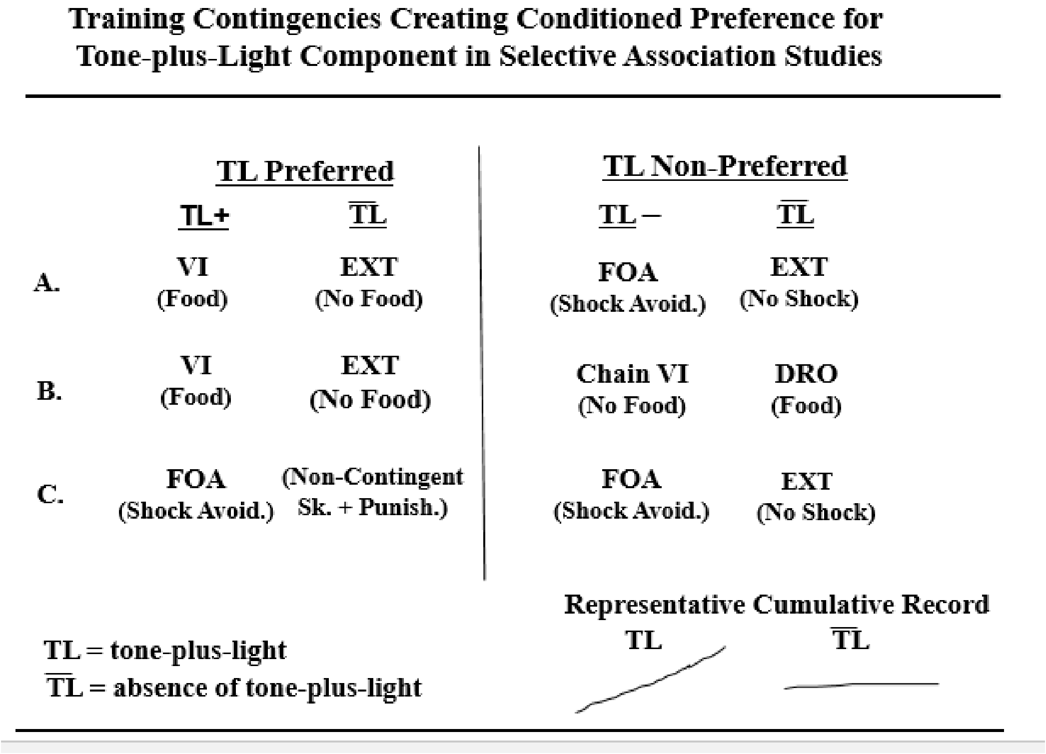
## Producing Selective Associations with Hedonically Positive and Negative Properties Established to the Auditory-Visual Compound Solely by Appetitive-Related Contingencies

Konorski’s (1967) appetitive-aversive-interaction theory of motivation offers a solution to the confound between class-of-reinforcer and conditioned preference discussed above. It postulates that when behavior is maintained by one class of reinforcer (appetitive or aversive), it should be: (1) energized by a conditioned excitor for that system *or* by a conditioned inhibitor for the other, and (2) weakened by a conditioned inhibitor for that system *or* by a conditioned excitor for the other. Overall, Konorski’s is a credible, symmetrical, parsimonious and integrative hedonically-based theory that has stimulated research and much supporting evidence. For example, stimuli paired with the absence of food share many properties with stimuli that have been paired with shock (Dickinson & Dearing, 1979) and stimuli paired with food are comparable in many situations to stimuli paired with the absence of shock (Hendry, 1967; LoLordo, 1969). [See also, Dickinson & Pearce (1977), Holmes et al. (2010), Weiss & Schindler (1989) and Weiss, Thomas, & Weissman (1996)].

That food-withdrawal and shock both create *negative hedonic states* suggested a solution to the confounding of food/shock with positive/negative hedonic states, respectively, described above. Weiss, Panlilio, and Schindler (1993a) produced positive or negative hedonic value to a tone-plus-light compound stimulus (TL) with appetitive contingencies in two groups of rats that were behaviorally comparable — emitting lever presses at a steady moderate rate during TL with pressing ceasing when that discriminative stimulus ($S^D$) was absentT́Ĺ**.**

Row B of Table 1 shows that their TL-Positive (TL+) Group earned all VI food reinforcers for lever pressing in TL and none in T́Ĺ, like Schindler and Weiss' (1982) did on their mult VI EXT training schedule (see Table 1, row A, left). In contrast, Weiss, Panlilio and Schindler's (1993a) TL-Negative (TL-) Group were on a chain schedule where lever pressing during TL produced T́Ĺon a VI schedule. In T́Ĺ all food was received for response cessation on a differential-reinforcement-of-other-behavior (DRO) schedule. This would be represented as a "chain VI DRO schedule". That these chain-schedule-trained rats worked to remove themselves from TL, and enter T́Ĺ, is clear behavioral evidence that TL was negative (or at least substantially less positive) compared to T́Ĺ. Nevertheless, their TL- Group's lever-pressing behavior was comparable to that of their TL+ Group. Both responded at steady-moderate rates in TL and ceased in T́Ĺ as represented in the lower right corner of Table 1.

**Table 1**



**Training Contingencies Creating Conditioned Preference for Tone-plus-Light Component in Selective Association Studies**

| | TL Preferred | | TL Non-Preferred | |
|---|---|---|---|---|
| | TL+ | $\overline{\text{TL}}$ | TL – | $\overline{\text{TL}}$ |
| A. | VI<br>(Food) | EXT<br>(No Food) | FOA<br>(Shock Avoid.) | EXT<br>(No Shock) |
| B. | VI<br>(Food) | EXT<br>(No Food) | Chain VI<br>(No Food) | DRO<br>(Food) |
| C. | FOA<br>(Shock Avoid.) | (Non-Contingent<br>Sk. + Punish.) | FOA<br>(Shock Avoid.) | EXT<br>(No Shock) |

TL = tone-plus-light
$\overline{\text{TL}}$ = absence of tone-plus-light

Representative Cumulative Record

After a subject's response rate in TL was at least 10 times its rate in T́Ĺ for three consecutive days, with no behavioral trend, a stimulus-element test was administered in extinction. On this test, the tone and the light were presented separately for the first time. Tone, light, and TL were each presented for 60 sec in the 12 randomized blocks that comprised this test. Test stimulus presentations were each separated by 60-sec $\acute{T}\acute{L}$ periods.

For the stimulus-element test results to be unambiguously interpreted, the groups need be equivalent in all ways save that the TL+ Group received all its food in TL while the TL- Group received all its food in $\acute{T}\acute{L}$. This equivalence is affirmed by the fact that the percent of their training sessions spent in TL was comparable (49.8% and 51.4%, respectively), as were their response rates in TL (13.9 and 12.9 per min, respectively) and session pellets per minute (1.2 and 1.5, respectively) – plus all subjects satisfied the 10:1 discrimination ratio between TL and $\acute{T}\acute{L}$ stimulus conditions.

Although the numerical comparisons over groups above clearly support their overall “comparability”, they do not provide any indication of the temporal patterning of the operant behavior of individual subjects in each group. Such important information is essential to conclude that the TL+ and TL- Groups are behaviorally comparable, because comparable average rates of behavior can be produced by an infinite variety of response distributions over time. The easiest (and most elegant) way to determine if the response patterns are similar is by looking at cumulative records.

Traditionally, a cumulative record of responding is created by a device that unrolls paper at a constant speed (creating the time axis) while a pen is incremented in a direction perpendicular to that axis by every response emitted. Therefore, (1) the absence of responding produces a horizontal line, (2) response rate is indicated by the record’s slope, (3) how responses are distributed over time is reflected by the record’s “fine-grain”, and (4) the quality of a subject’s stimulus control can also be ascertained by how abruptly its behavior changes upon transitions from one discriminative stimulus ($S^D$) to another. The cumulative records in Figure 3 can help the reader appreciate how this works.

Figure 3 contains representative cumulative records of all subjects from the TL+ and TL- Groups of Weiss et al. (1993a). They were trained on schedules known as multiple VI EXT and chain VI DRO, respectively (as detailed below), and are arranged according to each subject’s response rate in TL irrespective of its group. The cumulative records reveal that these two groups are behaviorally comparable, with the rats responding at generally steady-moderate rates in TL, and not responding in $\acute{T}\acute{L}$. Subjects from each group are evenly interspersed over the entire range of response rates in TL. Except for hatch-marks showing that the TL+ Group rats received food only in TL while those in the TL- Group rats received food only during $\acute{T}\acute{L}$, there is nothing the author has found in the fine grain of these records that distinguishes the groups. As explained above, concluding that the groups are behaviorally comparable requires such cumulative records because *averaged* rates, that were comparable over groups, can represent many different temporal response distributions and patterns.

The multiple VI EXT schedule was like the food schedule used in the earlier studies of selective associations (e.g., Schindler & Weiss, 1982), with responding producing food on a variable-interval schedule (VI) in the presence of TL, but with no food received (i.e., an extinction condition, EXT) in the absence of TL. (This will be represented as a mult VI EXT schedule.) Thus, the TL condition (food) would be more attractive compared to the absence of TL (no food), and this condition is designated TL+. In the chain VI DRO schedule, responding in TL did not produce food, but after a certain amount of time (VI) responding brought the TL schedule component to an end. Then, food was received in the absence of TL as long as no responses occurred for a certain amount of time (differential reinforcement of other behavior, DRO). Thus, the TL condition (no food) would be *less* attractive compared to the absence of TL (food). Therefore, for the chain VI DRO trained group the condition is designated TL.

While the TL+ and TL- Groups were behaviorally comparable, and the behavioral repertoires of both were maintained by food, (1) TL would have come to be the preferred condition for the group trained on the multiple VI EXT schedule where all food was earned in TL (Holz et al., 1963), while (2) TL would have become the non-preferred condition for animals trained on the chain VI DRO schedule where no food was earned in TL (Dinsmoor, 1983; Dinsmoor, Lee & Brown, 1986; Dinsmoor, Bowe, Green, & Hansen, 1988; Duncan & Fantino, 1972). Thus, Weiss et al. (1993a) eliminated, for the first time in the appetitive situation, the confounding of class of reinforcer (appetitive vs. aversive) and component preference that had beset such selective association studies for 20 years.

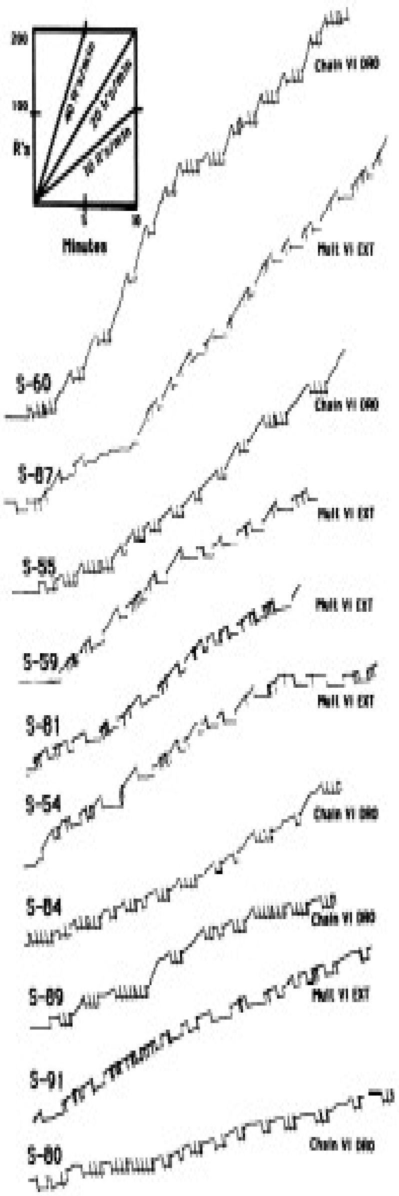


***Figure 3.*** Cumulative records of rats trained on mult VI EXT (to create TL+) and chain VI DRO (to create TL-) food-reinforcement schedules by Weiss et al. (1993a). They are from a criterion baseline session before a rat received its stimulus-element test. A rat's baseline schedule, chain VI DRO or mult VI EXT, is indicated to the right of each record. Records are presented in order of decreasing response rate in TL. Note that the two groups are evenly interspersed over the entire response-rate range. The pen in the upper register indicates a tone-plus-light (TL) component. During the absence of TL, the pen was in its lower register. Upward or downward slashmarks indicate food deliveries. If they were removed, the records would be indistinguishable over groups – the best evidence that the TL+ and TL- Groups were behaviorally comparable prior to testing. Therefore, the groups were comparable (see text for additional relevant comparisons) save for the fact that one received all its food reinforcers in TL (mult VI EXT) while the other received them only when TL was absent (chain VI DRO). From Weiss et al. (1993a).

While the TL+ and TL- Groups were behaviorally comparable, and the behavioral repertoires of both were maintained by food, (1) TL would have come to be the preferred condition for the group trained on the multiple VI EXT schedule where all food was earned in TL (Holz et al., 1963), while (2) TL would have become the non-preferred condition for animals trained on the chain VI DRO schedule where no food was earned in TL (Dinsmoor, 1983; Dinsmoor, Lee & Brown, 1986; Dinsmoor, Bowe, Green, & Hansen, 1988; Duncan & Fantino, 1972). Thus, Weiss et al. (1993a) eliminated, for the first time in the appetitive situation, the confounding of class of reinforcer (appetitive vs. aversive) and component preference that had beset such selective association studies for 20 years.

The distribution of test responses on Weiss, Panlilio and Schindler's (1993a) stimulus-element test is shown in the Figure 4 interaction profile. Although it is clearly similar to those presented earlier in Figure 1 (Foree & LoLordo, 1973; Weiss & Schindler, 1982), the reader should focus on the difference in stimulus control exerted by the elements over groups in this purely appetitive study. The chain VI DRO group (TL-) emitted only 39.6% of its element responses to the light while the multiple VI EXT group (TL+) emitted a significantly greater 65.0% of their element responses to the light. Table 2 ranks all 10 rats in the two groups responsible for the Figure 4 interaction profile according to the percentage of their stimulus=element test responses to the light element.

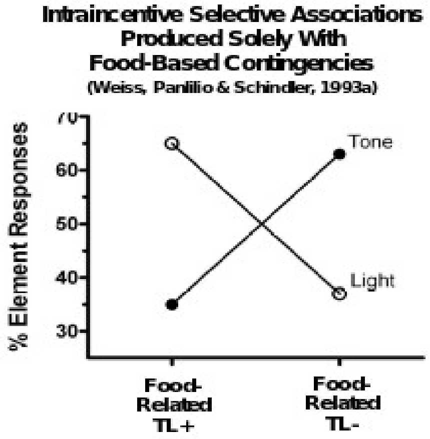


***Figure 4.*** The percentage of stimulus-element responses to the tone (filled circles) and the light (open circles) by the food-related TL + Group (mult VI EXT) and the food-related TL- Group (chain VI DRO) on their stimulus-element test. See Figure 1 for explanation of how these percentages were calculated. From Weiss et al. (1993a).

Table 2 shows that there was no group overlap in percentage of stimulus-element test responses controlled by the light element over TL+ and TL- Appetitive Groups. This attests to the strength of the underlying hedonic process responsible for this selective association produced solely with appetitive contingencies here. The rats in the appetitively-trained TL- Group in Figure 4 attended mainly to the tone, like the rats that avoided shock during TL in Schindler and Weiss' (1982) study presented in Figure 1, left frame. This comparison permitted Weiss et al. (1993a) to assert with some measure of confidence that this could be considered an *hedonically-based "stimulus-preference interaction"* that is not related to food or shock per se.

The hedonic analysis of selective associations should be generalized over classes of reinforcer, appetitive and aversive. Producing such a stimulus-preference interaction when TL+ and TL- conditions were both produced with shock-related contingencies in two-component free-operant schedules would support that generalization – as do Jacobs and LoLordo's (1977, 1980) findings in their transfer-of-control design experiment discussed earlier. This solely shock-produced stimulus-preference interaction profile after audio-visual compound training would contribute to parsimoniously relating selective associations in these situations to the fundamental psychological processes responsible for choice behavior in general and conditioned preference (deVilliers, 1977; Herrnstein, 1970). The potential unifying power of this integration over classes of reinforcer is clear. Collecting evidence germane to that generalization over classes of reinforcer was Weiss et al.'s (1993b) next objective.

**Table 2**

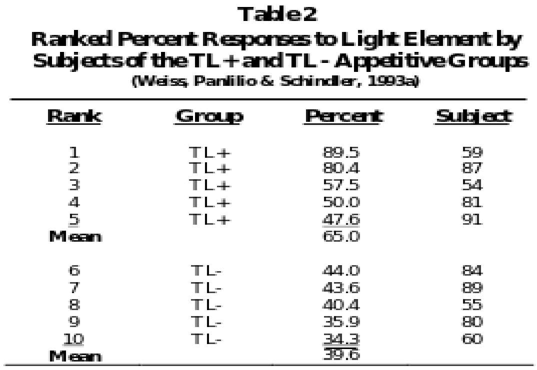


**Table 2**
**Ranked Percent Responses to Light Element by Subjects of the TL + and TL - Appetitive Groups**
(Weiss, Panlilio & Schindler, 1993a)

| Rank | Group | Percent | Subject |
|---|---|---|---|
| 1 | TL+ | 89.5 | 59 |
| 2 | TL+ | 80.4 | 87 |
| 3 | TL+ | 57.5 | 54 |
| 4 | TL+ | 50.0 | 81 |
| 5 | TL+ | 47.6 | 91 |
| **Mean** | | 65.0 | |
| 6 | TL- | 44.0 | 84 |
| 7 | TL- | 43.6 | 89 |
| 8 | TL- | 40.4 | 55 |
| 9 | TL- | 35.9 | 80 |
| 10 | TL- | 34.3 | 60 |
| **Mean** | | 39.6 | |

## Extending the "Hedonic States" Model Over Classes of Reinforcer: Selective Associations Produced with the Same Free-Operant Shock-Avoidance Contingency in TL for Both TL+ and TL- Groups

Table 1 classifies selective association experiments according to the relative preferences that would be conditioned to the TL and $\acute{T}\acute{L}$schedule components – with TL+ indicating an attractive, relatively positive hedonic value, and TL- indicating a repelling, relatively negative hedonic value. In addition, all contingencies would create these relative hedonic values while maintaining steady moderate responding in TL and response cessation in$\acute{T}\acute{L}$— as indicated by the representative cumulative records in the Table's lower-right corner. This shows that the discriminative control of responding was equated across all groups in TL and also in$\acute{T}\acute{L}$. Therefore, on a stimulus-element test group differences in the distribution of responses over the tone and the light element conditions can be attributed to the hedonically-related incentive-motive state produced when the subject enters the TL component.

Row A of Table 1 represents the confounded Foree and LoLordo (1973) and Weiss and Schindler (1982) studies presented in Figure 1 where different classes of reinforcer, food or shock avoidance, maintained responding in their two groups. Row B describes the Weiss et al. (1993a) experiment presented above where TL induced different hedonic states over groups solely through the indicated appetitive food schedules. This eliminated the class-of-reinforcer by conditioned-hedonic-state confound present in the selective association research represented in Row A. In a solely shock-related selective association paradigm, Row C presents the contingencies Weiss et al. (1993b) employed to create their TL+ and TL- Groups when the same free-operant shock-avoidance (FOA) contingency operated in TL for both groups.

Rats in their TL- Group postponed shock for 25 sec by lever pressing on an FOA contingency during TL while responding essentially ceased in T́ Ĺthat was shock-free (safe). By being differentially associated with shock here, TL came to increase the avoidance incentive, or more colloquially produced “fear”. Therefore, it would have become the non-preferred component compared to T́ Ĺ that was shock free. These training conditions are presented in Table 1, row C, right It is the same contingency as Schindler and Weiss’ (1982) employed with their TL- Shock Group (Table 1, row A, right) for whom auditory control predominated in Figure 1, left frame. So this is a systematic replication of that group.

Producing a TL+ Group here was more challenging. To accomplish that, Weiss et al.’s (1993b) rats’ also postponed shock for 25 sec on an FOA schedule by lever pressing in TL, just as their TL- Group described above did. But, for their TL- Group shock-related contingencies were programmed in T́ Ĺ designed to make it more aversive, and thus more “feared”, than TL. To accomplish this, in T́ Ĺ unsignalled-unavoidable shocks were delivered intermittently plus lever pressing was punished by producing immediate shock. Punishment was necessary here because a schedule of non-contingent shock can lead to substantial rates of responding in avoidance-trained rats over many sessions — and this is especially potent when there is an avoidance schedule still operating in another schedule component — as it was here during TL (Panlilio & Weiss, 1993). But what is the evidence that FOA related TL would be less *feared* than, and therefore preferred over, T́ Ĺafter this training?

From the work of Badia and Culbertson (1972), it follows that signaled-avoidable shock should be preferred to unsignalled-inescapable shock. Therefore, entering the TL component should have reduced the aversive incentive-motivation for Weiss et al.’s (1993b) TL+ Group because therein shock was: (1) *predictable* from time elapsing since a subject’s response (Anger, 1963) rather than unpredictable, and (2) *controllable* since it could be avoided. Contrast that with this group’s T́ Ĺcondition during which shock was unpredictably presented independent of the subject’s behavior (i.e., uncontrollable) plus produced by lever pressing.

Therefore, shock predictability as well as controllability both contributed to TL reducing *fear*, and thereby becoming a relative TL+, even though shocks occurred during TL and T́ Ĺconditions in Weiss et al.’s (1993b) TL+ group. This is further supported by the instrumentally-derived aversive incentive-motivational function Weiss (2014a, 2014b) recently published. That function contained a group trained comparably to the TL+ group described above. Its test results confirm that entering TL, wherein FOA operated, reduced their aversive incentive-motivation, *fear*.

This evidence supports that Weiss et al.’s (1993b) experiment eliminated, in an aversive shock-related situation, the confounding of class of reinforcer and component preference -- just as Weiss et al. (1993a) did in a food-related, appetitive experiment that produced selective-associations. In addition, Weiss et al. (1993b) might even be viewed as going a step beyond that study because both of their groups, TL+ and TL-, were on exactly the same FOA contingency in TL. For both groups, in TL lever pressing postponed shock by 25 sec [the response-shock (RS) interval] while in the absence of pressing a shock was presented every 5 sec [the shock-shock (SS) interval). This was an RS-25-sec SS 5-sec FOA contingency (Sidman, 1953).

Weiss et al.’s (1993b) Table 1 shows their TL+ and TL- Groups were behaviorally comparable prior to receiving the stimulus element tests. Their rates in TL were 7.1 and 6.6 responses/minute, respectively, while their rates in $\acute{T}\acute{L}$ were 0.3 and 0.2 responses/minute, respectively. Both groups received 0.4 shocks/minute in TL. During $\acute{T}\acute{L}$, the TL- Group received no shocks (extinction) while the TL+ Group received 0.4 shocks/min therein on a non-contingent shock plus punishment contingency.

Unfortunately, the cumulative records of Weiss et al.’s (1993b) rats are no longer available. But cumulative records from rats trained on essentially the same schedule are. These are presented in Figure 5, and described in its caption, to show that the shock-related contingencies Weiss et al.’s (1993b) used to create their TL+ and TL- shock-related conditions can, in fact, produce comparable behavioral control.

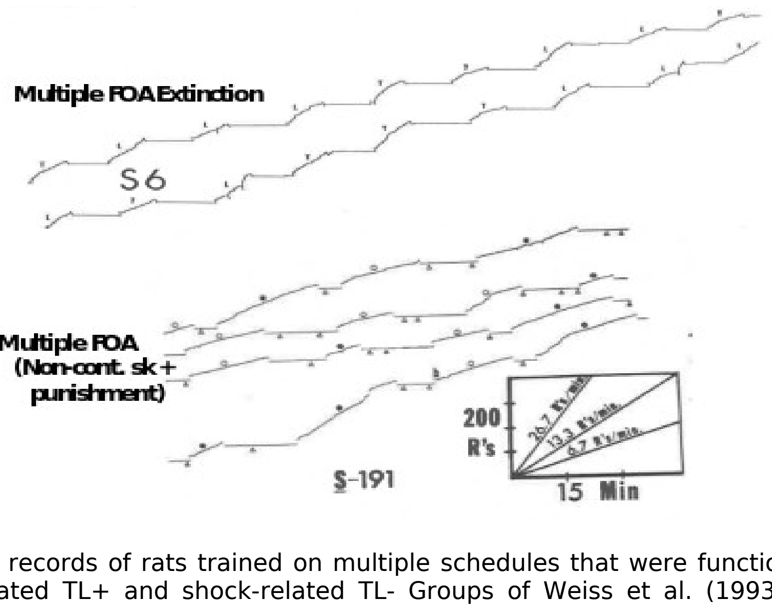


***Figure 5.*** Cumulative records of rats trained on multiple schedules that were functionally comparable to those of the shock-related TL+ and shock-related TL- Groups of Weiss et al. (1993b). Both rats lever pressed at steady moderate rates to postpone shock (hatch-marks) in tone (T-or-filled circles) and in light (L-or-open circles) $S^D$s. Pressing ceased when these $S^D$s were absent ($\acute{T}\acute{L}$ (pen depressed). But (see text),

in the context of the condition programmed in T́ Ĺ [safety (S-6) or noncontingent shock + punishment (S-191) these $S^D$s *increased* avoidance incentive (“fear”) in S-6 and *decreased* it in S-191. Therefore, although the same free-operant avoidance schedule operated in the $S^D$s of both schedules the $S^D$s would have been, relative to T́ Ĺ, hedonically negative for S-6 and hedonically positive S-181. S-6 from Emurian and Weiss, (1972). S-191 from Weiss (1976, Exp. 3).

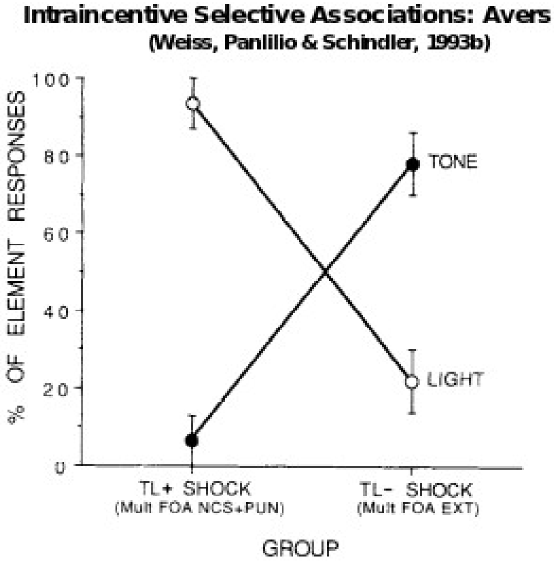


***Figure 6.*** The mean percentage of stimulus-element test responses emitted in the tone (T: filled circles) and in the light (L: open circles) by the shock-related TL+ and TL- Groups of Weiss et al. (1993b). See Figure 1 caption for explanation of how these percentages were calculated. TL+ = tone-plus-light was established as hedonically positive (preferred) relative to its absence, T́ Ĺ;TL- = tone-plus-light was established as hedonically negative (non-preferred relative to T́ Ĺ; Mult = multiple; FOA = free-operant avoidance; NCS = noncontingent shock; PUN = punishment; EXT = shock-free extinction. From Weiss et al. (1993b).

Figure 6 presents the stimulus-element test results of Weiss et al.’s (1993b) TL+ and TL- FOA shock-related groups. The tone and the light were presented singly for the first time on this test. It is immediately apparent that the TL+ Group was almost entirely under control of the light element even though it had received shock therein. This is, in fact, greater control by the light element than had ever been reported with rats or pigeons for which TL+ had associated with food as shown in Figure 1. In stark contrast, for the TL- Group, that avoided shock in TL on exactly the same RS-25-sec SS 5-sec FOA contingency as the TL+ Group, almost 80% of its stimulus-element test responses were emitted during the tone — even thought it was in the presence of the tone and the light elements for the same total time over the test. The TL- Group here systematically replicated Schindler and Weiss’ (1982) rats in Figure 1, left, that also avoided shock in TL whileT́ Ĺwas shock free.

The concentration of subject scores around each data point in Figure 6 is noteworthy. Just as in the appetitive-only selective association profile in Figure 4, there was nothing close to group overlap here in the aversive-only stimulus-preference interaction profile. Taken together, these findings strongly support that conditioned hedonic states are responsible for audio-visual selective associations in rats. Since selective associations are a “biological-constraint-on-learning”, the next logical step is to determine if the hedonic-state analysis of this phenomenon can be extended to another species.

## Extending the Hedonic Model of Selective Associations over Species: Single Incentive Selective Associations in Pigeons

After discrete-trial operant training in which an appetitive or aversive reinforcer (food or shock) was differentially associated with a TL compound, pigeons produce a selective-association interaction profile (shown in the right frame of Figure 1) on a stimulus-element test (Foree & LoLordo, 1973). Since “the more widespread the generality of a constraint, the more important it is to develop a better understanding of its mechanism” (Panlilio & Weiss, 2005, pp. 419-420), we sought to determine whether the hedonic-related process observed in rats could also be responsible for selective associations in pigeons. This could be especially informative and integrative because rats (mammals) and pigeons (avians) represent distinct phylogenetic classes -- and because pigeons are clearly more biased towards visual cues than are rats.

In these pigeon experiments by Panlilio and Weiss (2005), an effort was made to insure that the pigeon and rat training procedures were as comparable as possible. To accomplish this comparability: (1) the operant used with pigeons was treadle hopping, an arbitrary response in relation to food or shock much as lever pressing is arbitrary for the rat[1]; (2) to make the auditory elements of grain hopper operation functionally similar to the feeder click paired with food in the rat studies, *no hopper light* was used with the pigeons' grain hopper; and (3) birds trained on the free-operant shock-avoidance schedules were implanted with stainless steel electrodes using Azrin’s (1959) procedure, with the coiled cable from the shocker attached to the pigeon’s jacket so as not to restrain the birds movement.

The auditory and visual stimuli were chosen to be similar to those used with pigeons by Foree and LoLordo (1973, 1975). The tone was 440 Hz, at 80 dB. A white 15 W houselight and a red 60 W stimulus light were situated behind one of the translucent walls to the right of the front wall with the treadle and food hopper. These lights illuminated the entire chamber. The red and white lights were operated so that whenever the red light was on, the white light was off, and vice versa. Thus, the TL compound discriminative stimulus consisted of the tone plus the red light. The absence of TL, represented as $\dot{T}\acute{L}$, consisted of tone off, red light off and white light on. This low-level white light is analogous to the continuously on dim houselight that slightly illuminated the chamber during the $\dot{T}\acute{L}$periods in all the experiments described thus far where rats were the subjects.

Panlilio and Weiss (2005) created TL+ and TL- conditions in pigeons with the traditional appetitive-aversive (food-shock) selective association training paradigm (Table 1, row A) also appetitive-only (Table 1, row B) and aversive-only (Table 1, row C)

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[1] The term *arbitrary* is used here to mean that rats and pigeons do not enter the experimental situation naturally predisposed to press a lever or treadle, respectively, to either acquire food or escape/avoid an aversive event. However, these behaviors are readily engaged in and have been shown to be sensitive to operant contingencies.

training paradigms described in detail above in experiments in the analogous single-incentive selective association research with rats. A pigeon was trained until it met at least an 8:1 ratio of response rate in TL versus $\acute{T}\acute{L}$ for five consecutive sessions — with most pigeons surpassing a 10:1 ratio. Then, a pigeon received a block-randomized stimulus-element test that consisted of 24 blocks. Within each block, the tone, the red light, and the tone-plus-red light compound were each presented for 60 sec, with each of these test stimuli followed by 60 sec of $\acute{T}\acute{L}$.

The results of these tests are presented as interaction profiles in Figure 7, as for the studies described above. The left frame of Figure 7 presents the traditional between-incentive, food-versus-shock selective association. It systematically replicates with free-operant training the appetitive–aversive interaction profile originally reported by Foree and LoLordo (1973) in pigeons with discrete-trial operant training. Note that this free-operant replication of Foree and LoLordo provided the necessary reference conditions for the single-incentive profiles in the other two frames of Figure 7. The center frame of Figure 7 shows the appetitive single-incentive interaction profile produced by pigeons that were trained like the rats of Weiss et al. (1993a) whose test profiles are shown in Figure 4, above. The right frame of Figure 7 shows the aversive single-incentive interaction profile produced by pigeons that were trained like the rats of Weiss et al.’s (1993b) whose test profiles are shown in Figure 6, above.

The appetitive-aversive and aversive only profiles in the left and right frames of Figure 7 are essentially indistinguishable from the respective profiles reproduced by rats in the left frame of Figure 1 (traditional appetitive-aversive selective association; Weiss & Schindler, 1982) and in Figure 6’s aversive single-incentive selective association from Weiss et al. (1993b). In the center frame of Figure 7 (appetitive-only interaction profile), it can be seen that in pigeons the TL- Food condition did not enhance auditory control (relative to the TL+ Food condition) as much as the TL- conditions of the right and left frames of Figure 7, or in any of the rat experiments (Figures 1, 2, 4 and 6). However, even though the auditory element did not achieve outright dominance in TL- Appetitive-Only condition with pigeons here, as it did with rats (Weiss et al. (1993a), TL- Food training did produced statistically significant enhancements of auditory stimulus control in both rats (Figure 4 above) and pigeons (Figure 7 center frame) compared to TL+ Food training. Whether this smaller effect in pigeons versus rats is due to different dominant sensory modalities in the two species and/or other reasons remains to be determined. But it should be noted that significant, close to intersecting, single-incentive appetitive selective association interaction profiles have also been reported with rats (Weiss et al., 1993b, Figure 4).

Panlilio and Weiss (2005, p. 427) concluded, "It is probably more important to understand a constraint on learning that occurs across a variety of species, rather than in a single species. A more general constraint could be indicative of a [shared] fundamental … psychological process." The hedonic manipulations described above had similar effects in both rats and pigeons. Therefore, the hedonic state that comes to be induced by an audio-visual compound through the contingencies operating in the organism’s world influences the modality attended to across rather divergent species -- mammalian and avian. That would suggest this constraint, with its underlying mechanisms, conveyed some evolutionary advantage to both species.

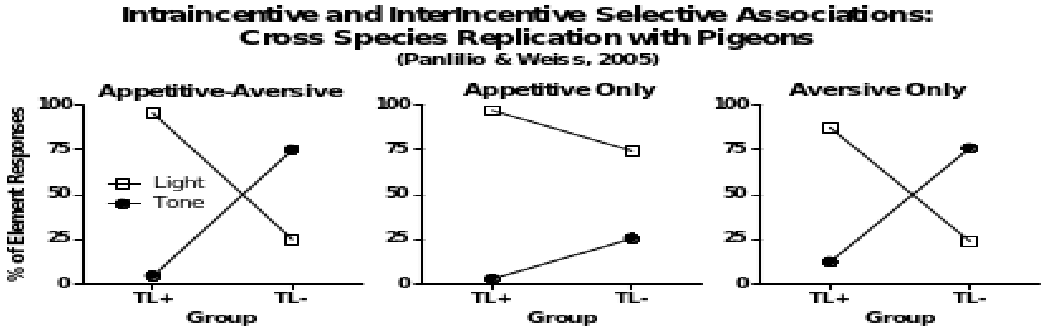

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*Figure 7*. Pigeon interaction profiles showing: (A) the ‘‘traditional’’ appetitive–aversive selective-association effect between free-operant trained TL+ Food and TL- Shock Groups; (B) the appetitive single-incentive selective-association effect between free-operant trained TL+ Food and TL- Food Groups; and (C) the aversive single-incentive selective-association effect between free-operant trained TL+ Shock and TL- Shock Groups. See Figure 1 for explanation of how these percentages were calculated. Adapted from Panlilio and Weiss (2005).

## Reversing a Selective Association

Schindler and Weiss (1982) were the first to test whether a selective association could be reversed. They used a within-subject design with the traditional appetitive-aversive selective-association paradigm presented in Table 1, row A with their reversal paradigm outlined in Table 3. Over Phases 1 and 2, the reinforcer maintaining responding in the TL compound for the two groups in Table 3 was reversed — from food to shock avoidance or vice-versa. In all conditions extinction was programmed during T́Ĺ.

After a rat’s response rate in TL was at least 10 times its rate in T́Ĺ for four consecutive sessions, it received a stimulus-element test in extinction, like those described above. After this Phase 1 test, the reinforcer maintaining a rat’s responding in TL was switched from food to shock avoidance or vice-versa. This Phase 2 reversal training continued until the 10:1 discrimination criterion was met, and the rat was tested again. Figure 8, top frames, shows that, in the original as well as reversal training phases, the traditional selective-association effect was obtained: training produced mainly visual control when TL was differentially associated with food reinforcement, while training produced mainly auditory control when TL was differentially associated with avoiding shock. This multiphase investigation demonstrated that the appetitive-aversive selective association could be completely reversed by training with the opposite condition.

Surprisingly, a prior history where responding in TL was maintained by the other reinforcer did not have much, if any, effect on the selective associations in Figure 8. They appeared to be determined solely by the contingency conditions producing the *current* hedonic value of TL+ and TL-. The influence, or carry over, of previous hedonic values acquired by the compound stimulus were not apparent, at least with this test. Perhaps a test could be created that would be sensitive to a history with the opposite hedonic state in the audio-visual compound. Phenomena such as reinstatement renewal (Bouton, 2004; Kearns & Weiss, 2005; (Rescorla & Heth, 1975) show that previous learning is not lost. However, it should be recognized that in those situations the association was usually weakened though extinction rather than counter conditioned as in the selective-association reversal studies.

**Table 3**

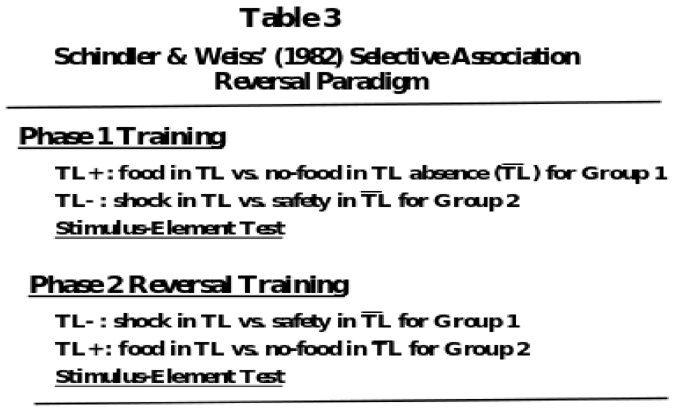

**Table 3**

**Schindler & Weiss' (1982) Selective Association Reversal Paradigm**

**Phase 1 Training**

TL+: food in TL vs. no-food in TL absence ($\overline{TL}$) for Group 1
TL- : shock in TL vs. safety in $\overline{TL}$ for Group 2
Stimulus-Element Test

**Phase 2 Reversal Training**

TL- : shock in TL vs. safety in $\overline{TL}$ for Group 1
TL+: food in TL vs. no-food in TL for Group 2
Stimulus-Element Test

Panlilio and Weiss (1993) went on examine whether selective associations would also be reversible when TL+ and TL- were created solely with the appetitive or solely with the aversive contingencies described in rows B and C of Table 1, respectively. Their within-subject design was modeled on Schindler and Weiss' (1982) appetitive-aversive (i.e., food and shock) reversal design described above. For their Phase 1 single-incentive profiles, Panlilio and Weiss (1993) used those produced by the rats originally trained by Weiss et al. (1993b) and presented in Figures 2 and 4 of that study. These profiles revealed (1) predominant visual control whether TL+ was created with solely food-related or solely shock-related contingencies, and (2) that auditory control increased significantly when TL- was created solely with food-related or solely with shock-related contingencies. These "Appetitive Only" and "Aversive Only" interaction profiles are shown in the Phase 1 middle left and lower left frames of Figure 8, respectively.

Panlilio and Weiss (1993) continued training these Weiss et al. (1993b) rats into a Phase 2 wherein their contingencies were switched intraincentively. Their reversal design is presented in Table 4. In this within-subject design, the rats that were on the TL+ food schedule in Phase 1 were switched in Phase 2 to the TL- food schedule and vice-versa (see Table 1, row B and the left column of Table 4). Likewise, the rats that were on the TL+ shock schedule in Phase 1 were switched in Phase 2 to the TL- shock schedule and vice-versa (see Table 1, row C and the right column of Table 4). This was designed to produce for each rat in Phase 2 a hedonic value to the TL discriminative stimulus that was opposite to that established in Phase 1. The middle and bottom right

Phase 2 frames in Figure 8 show the interaction profiles for these groups when the contingencies were switched to make their TL+ a TL- and vice-versa (see Table 4).

It is absolutely clear that contingency reversal again had no effect on the interaction profile resulting from the stimulus-element test. In that regard, the hedonic change in TL Panlilio and Weiss (1993) produced by intraincentive manipulations over phases was comparable that produced by the interincentive change (food/shock) of Schindler and Weiss (1982). This again accentuates the importance of the *current* hedonic nature of the contingency-related psychological states in TL, rather than the physical nature of the conditions in TL themselves. The TL compound having a past history with the opposite hedonic state didn't seem to matter whether the hedonic state was created interincentively or intraincentively! This clearly supports the hedonic model of selective associations.

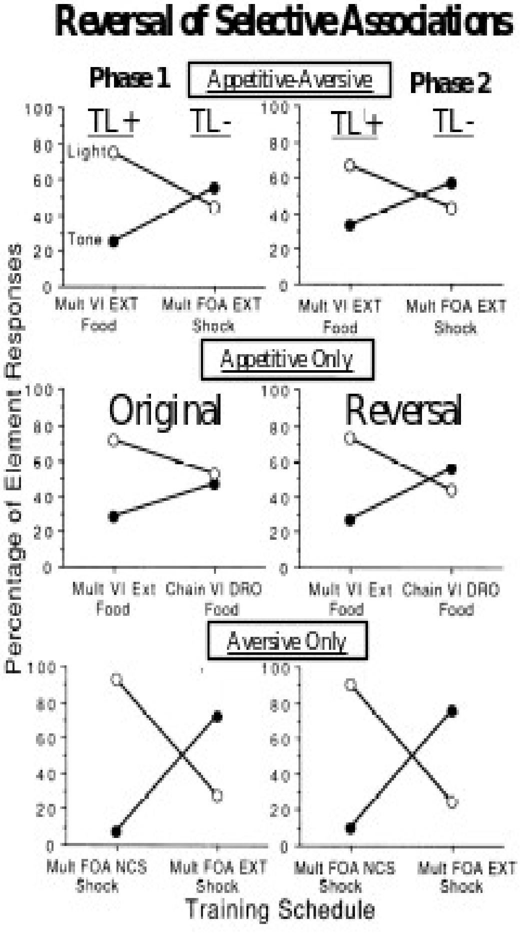

***Figure 8.*** Interaction profiles of experiments concerned with the reversal of selective associations. The top frames present the results Schindler and Weiss' (1982) appetitive-aversive trained groups. The Intraincentive-appetitive and Intraincentive-aversive reversal experiments of Panlilio and Weiss (1993) are presented in the middle and bottom rows, respectively. For each experiment, profiles in the left panels represent the stimulus-element test results from the original training phase. Those in the right panels represent results obtained with the same rats after their training schedules were switched in Phase 2. Therefore, although the x-axes in the Phase 1 (Original Training) and Phase 2 (Reversal Training) are the same, (1) the contingencies on the x-axis under Phase 1 represent the first, and only, contingency these rats had experienced in TL until then, while (2) the contingencies on the x-axis under Phase 2 represent the second contingency these rats experienced in TL after having been brought under stimulus control on the

other contingency in Phase 1. See Figure 1 caption for a description of how these percentages were calculated. Adapted from Panlilio and Weiss (1993).

In nature, this type of adaptability to changing conditions could be advantageous, and from that perspective shouldn't be surprising. But despite this strong sensitivity to the current conditions, can the predisposition for visual control favored by hedonically positive states and auditory control strengthened by hedonically negative states be altered by a powerful associative learning procedure like blocking? That will be discussed next.

## Blocking a Selective Association

The evidence presented above demonstrated that it was the current relative hedonic value of the TL compound, relative to $\dot{T}\acute{L}$, that is responsible for selective associations. However, there is evidence that selective associative associations can be modified with the powerful blocking procedure introduced by Kamin (1969). Schindler and Weiss (1985) employed that procedure to block a stimulus–reinforcer interaction in rats by bringing lever pressing under the control of the biologically-contingency-disadvantaged element of the compound stimulus prior to compound-stimulus training.

**Table 3**

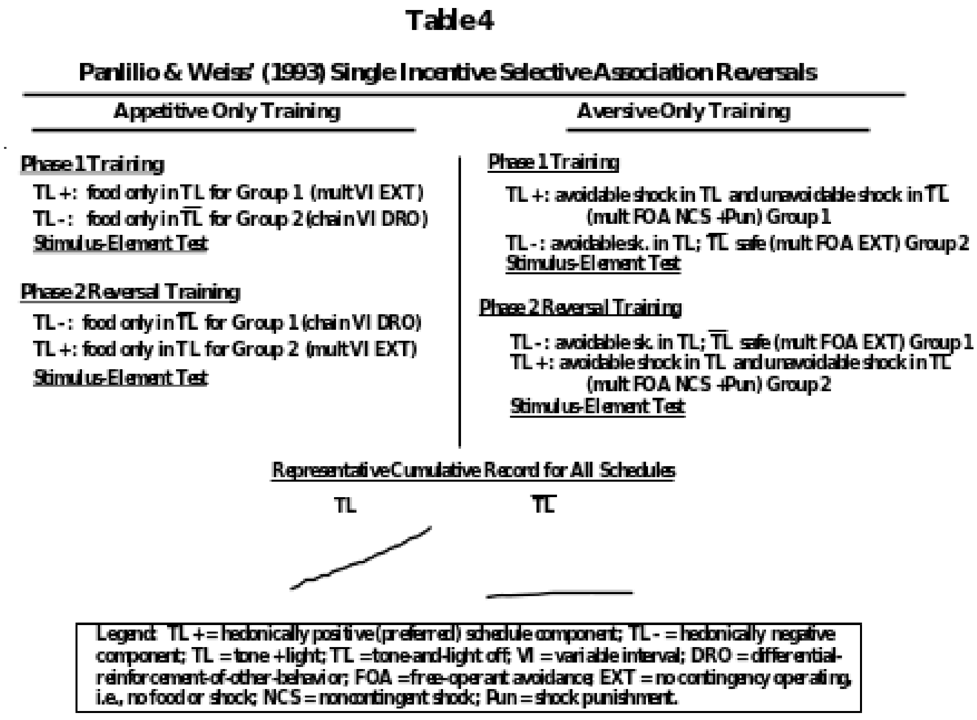

**Table4**

**Panlilio & Weiss' (1993) Single Incentive Selective Association Reversals**

**Appetitive Only Training**

Phase 1 Training
TL +: food only in TL for Group 1 (mult VI EXT)
TL - : food only in $\overline{TL}$ for Group 2 (chain VI DRO)
Stimulus-Element Test

Phase 2 Reversal Training
TL - : food only in $\overline{TL}$ for Group 1 (chain VI DRO)
TL +: food only in TL for Group 2 (mult VI EXT)
Stimulus-Element Test

**Aversive Only Training**

Phase 1 Training
TL +: avoidable shock in TL and unavoidable shock in $\overline{TL}$ (mult FOA NCS +Pun) Group 1
TL - : avoidable sk. in TL; $\overline{TL}$ safe (mult FOA EXT) Group 2
Stimulus-Element Test

Phase 2 Reversal Training
TL - : avoidable sk. in TL; $\overline{TL}$ safe (mult FOA EXT) Group 1
TL +: avoidable shock in TL and unavoidable shock in $\overline{TL}$ (mult FOA NCS +Pun) Group 2
Stimulus-Element Test

Representative Cumulative Record for All Schedules

Legend: TL + = hedonically positive (preferred) schedule component; TL - = hedonically negative component; TL = tone + light; TL = tone-and-light off; VI = variable interval; DRO = differential-reinforcement-of-other-behavior; FOA = free-operant avoidance; EXT = no contingency operating, i.e., no food or shock; NCS = noncontingent shock; Pun = shock punishment.

Their food-group rats initially lever pressed for food in the presence of a tone, while food was unavailable (extinction) in the absence of the tone. After this single-stimulus discrimination was firmly established, a light was added to the tone, creating a TL compound $S^D$, for 15 additional training sessions. Training for a group of shock-trained rats was symmetrical to this food training. That is, rats in the shock-avoidance group were pretrained to avoid shock during the biological-contingency-disadvantaged light, while the absence of light was shock free (extinction). Then, a tone was added to the light, creating a TL compound $S^D$, and training continued for 15 additional sessions.

Results Schindler and Weiss (1985) obtained on stimulus-element tests after this single-stimulus pretraining procedure are presented in the right frame of Figure 9. Strikingly, the traditional appetitive-aversive selective association interaction profile produced by Schindler and Weiss' (1982) compound-only trained rats (in left frame of Figure 9) was not just eliminated, as might have been conservatively anticipated. The blocking procedure completely reversed the interaction profile even after 30-60 hours of compound-stimulus training that should have given the biologically predisposed stimulus to gain some association. In the shock condition of Figure 9, right frame, it was as though the pretraining with light "turned off" their ears even though rats (1) favor the audio modality, and (2) are biologically predisposed to associate an aversive condition with an auditory stimulus.

Again, as with the basic demonstrations of within and between incentive selective associations, the question of cross-species generality arises with respect to blocking this phenomenon. In pigeons, would the "natural" connection between the dominant visual modality and food be as overwhelmed by pretraining with the biologically-disadvantaged tone as it was in rats? Weiss and Panlilio (1999) went on to investigate the effect pretraining pigeons with the biologically-disadvantaged stimulus with respect to the reinforcer maintaining responding (tone-food and light-shock) prior to compound-stimulus training.

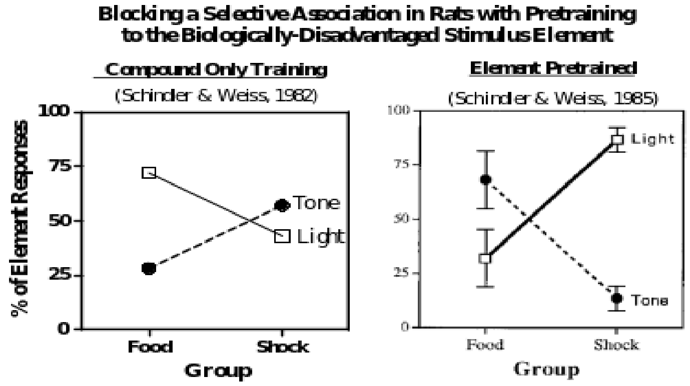

***Figure 9***. Right frame: The interaction profile showing results of the stimulus element test for rats pretrained with the biologically-contingency-disadvantaged element prior to tone-plus-light compound stimulus training. The pretrained stimulus was a tone for the food group and a light for the shock group. The mean percentages of responses emitted in the presence of the tone (filled circles) and light (open squares) are shown for these groups. See Figure 1 caption for explanation of how these percentages are calculated. This profile was derived from data presented in Schindler & Weiss, 1985). Left frame: The selective association interaction profile of Schindler and Weiss' (1982) compound-only trained rats. For each group, the compound stimulus set the occasion to respond for food or to avoid shock from the onset of discrimination training. Adapted from Schindler and Weiss (1982, 1985).

As detailed above in the “Single Incentive Selective Associations in Pigeons” section of this article**,** we again sought to make the pigeon and rat training procedures as comparable as possible. One especially important component of that objective will be repeated: To make the auditory elements of grain hopper operation functionally similar to the feeder click paired with food in the rat studies, *no hopper light* was used with the pigeons' grain hopper. This eliminated the potential association of this visual cue with food during auditory pretraining – something that must be avoided to maintain the integrity of the blocking design. The pigeon only heard the sounds produced by hopper operation!

As described above, Schindler and Weiss (1982) blocked selective associations in rats trained on multi-component free-operant contingencies. Therefore, if Weiss and Panlilio (1999) were to systematically replicate (Sidman, 1960) this blocking in pigeons they had to first produce traditional selective associations in pigeons trained on multi-component free-operant contingencies like those Schindler and Weiss employed with rats.

To accomplish that, in Experiment 1 Panlilio and Weiss’ (1999) appetitive-trained pigeons treadle pressed to produce food on a variable interval (VI) schedule in a TL compound S$^D$ (tone plus red light) while food wasn’t available [extinction (EXT)] in $\acute{T}\acute{L}$ (tone off, red light off and dim white light on). Their aversive-trained group of pigeons treadle pressed to postpone shock on a free-operant avoidance (FOA) schedule in a TL compound S$^D$ while $\acute{T}\acute{L}$was shock free (EXT). After reaching at least a 9:1 discrimination criterion between TL and $\acute{T}\acute{L}$for three consecutive sessions, a stimulus-element test was administered to these pigeons. Figure 10 outlines their compound-stimulus only training paradigm and presents the selective association interaction profile produced from the results of these pigeon’s stimulus-element test. It is at least as strong as, if not more pronounced than, that produced by Foree and LoLordo’s (1973) discrete-trial audio-visual trained pigeons shown in the left frame in Figure 1 of this article.

**Compound-Only Training with Pigeons**
**(Weiss & Panlilio. 1999)**

| Group | Training | Element Test |
|---|---|---|
| Food | Tone+Light: R → Food | Tone, Light |
| Shock | Tone+Light: R → Avoid Sk | Tone, Light |

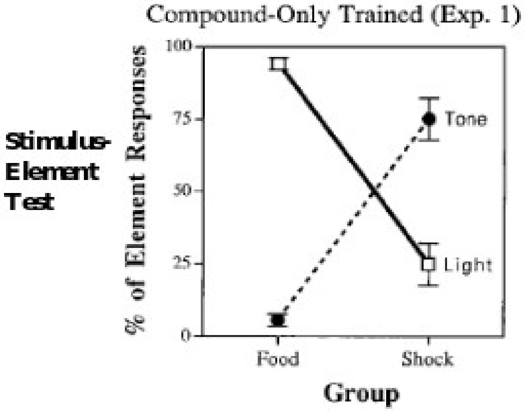

***Figure 10***. Training outline and selective association interaction profile showing the stimulus-element test results of compound-only trained pigeons (Panlilio & Weiss, 1999, Exp. 1). The mean percentage of total element responses emitted in the presence of the tone (filled circles) and light (open squares) are shown for groups trained with food or with shock. See Figure 1 caption for explanation of how these percentages are calculated. These results are a systematic replication of the stimulus–reinforcer interaction with pigeons trained on multiple schedules of reinforcement rather than with discrete-trials (Foree & LoLordo, 1973).

Then, Weiss and Panlilio (1999) were ready to investigate how “blocking” would affect selective associations in pigeons. To accomplish that, they essentially replicated with their pigeons Schindler and Weiss’ (1985) blocking procedure described at the beginning of this section and also outlined in the top portion of Figure 11. Before compound-stimulus training, pigeons in the food and shock avoidance groups were pretrained with the biologically-contingency-disadvantaged stimulus. That is, tone alone was established as a discriminative stimulus for food-reinforced responding in the food group, and light alone was established as a discriminative stimulus for avoidance responding in the shock group. In both groups, when the stimulus element was off they were in extinction – which meant no food for the food group and safety for the shock group. This discrimination training continued until a pigeon was responding at least nine times as rapidly during its single stimulus element, than when it was absent, for three consecutive days. Then, in Phase 2 its discrimination training continued, but between TL and $\acute{T}\,\acute{L}$, for 15 additional 2-3 hr sessions. At that point a pigeon received a stimulus-element test like those described earlier.

As seen in Figure 11, the blocking procedure completely prevented the traditional selective association in pigeons, just as it did with rats. The food group was predominantly under control of the auditory stimulus, and the shock group was almost exclusively under control of the visual stimulus. As is abundantly clear in Figure 12, this is the reverse of the results produced by their compound-only trained pigeons.

As with rats, pretraining pigeons with their biologically disadvantaged element did not merely eliminate the selective association. It actually reversed the association! We have consistency here in the effects of disadvantaged-element pretraining across species with different dominant modalities. In fact the similarity of the interaction profiles produced by pretrained rats (Figure 9, right frame) and by pretrained pigeons (Figure 12, right frame) is striking. That supports how powerful an influence reinforcement contingencies can have on this, and likely other, biological-constraints-on-learning[2]. However, the presumed *natural* connection of pigeon’s dominant visual modality and food did not appear to be as overwhelmed by tone-food pretraining as the rat’s presumably favored “natural” connection between the auditory modality and shock was by light-shock pretraining. However, their element-pretrained shock data is very similar (left frames of Figures 9 and 12). Although they are intriguing, comparisons like this over species are only suggestive at best.

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[2] The author (SJW) presented a talk on *Hedonics and Selective Associations* at the 2015 *Art and Science of Animal Training Conference* in Denton, Texas. He followed this sentence with, “... on the basis of selective associations being actually reversed by the blocking contingency he would expect that even some of the apparently contingency-resistant raccoon behaviors the Brelands worked with were modifiable with the appropriate contingency interventions.” At that instant, Robert Bailey, who had worked with the Brelands (see Bailey & Gillaspy, 2005), raised his hand and shared, according to the author’s recollection, “That was, in fact, the case but we were too busy to publish the data.”

**Pre-training Pigeons with Biologically-Disadvantaged Element**

(Weiss & Panlilio, 1999)

| Group | Phase 1-Element Trn. | Phase 2-Compound Trn. | Element Test |
|---|---|---|---|
| Food | Tone: R → Food | Tone+Light: R → Food | Tone, Light |
| Shock | Light; R → Avoid Sk | Tone+Light; R → Avoid Sk | Tone, Light |

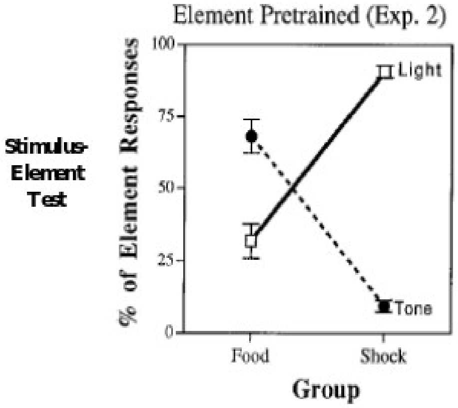

***Figure 11.*** Training outline and selective association interaction profile showing the stimulus-element test results of pigeons pretrained with the biologically-contingency-disadvantaged element prior to compound-stimulus training by Weiss and Panlilio (1999,Exp. 2). See Figure 1 caption for explanation of how these percentages are calculated. The pretrained stimulus was dominant in each group, demonstrating that the stimulus–reinforcer interaction was reversed.

Before concluding this section, the previous, unsuccessful attempt of LoLordo, Jacobs and Foree (1982) to block a selective association in pigeons deserves discussion. Weiss and Panlilio (1999) presented the following analytical comparison of their procedure and LoLordo et al's. (1982, which could account for the differences in their results):

> LoLordo et al.'s (1982) procedures included many response-correlated and reinforcer correlated stimulus changes that were unrelated to, and could even have conflicted with the stimulus–reinforcer associations that were the objective of their pretraining, tone-food and light-shock. They employed discrete-trials training wherein a pigeon's first treadle press in the 5-s stimulus produced 5-s access to an illuminated [italics added] grain-filled magazine (food group) or avoided shock (shock group) while simultaneously terminating the stimulus. Thus, in their pretrained food group, tone control might have been compromised when tone offset and a hopper-light onset signaled grain. In addition, intertrial interval responses darkened the chamber briefly (160 ms) for all pigeons. This variety of stimulus changes potentially created ''noise'' that could have contaminated their intended pretrained element associations. In contrast, Schindler and Weiss' (1985) design, and that of the present Experiment 2, were intended to minimize response-correlated and reinforcer-correlated stimulus changes unrelated to their central pretraining stimulus–reinforcer contingencies, tone-food and light-shock –*[plus there was no hopper light* [italics added] in the present pigeon experiment, only the sound of the hopper operating.*]* (Weiss & Panlilio, 1999, p. 22.)[3].

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[3] A similar audio-visual hopper-related problem can be found in a transfer-of-control design experiment wherein Reed-Elder and LoLordo (1985) demonstrated visual dominance in pigeons not only when learning about food reward, but also when learning about the absence of food reward. On the surface, this seems inconsistent with the current emphasis on hedonics that would predict auditory stimuli more successful than visual stimuli at acquiring inhibitory control involving food reward. Unfortunately, these results cannot be unambiguously evaluated because a hopper light plus the sounds of the hopper operation signaled food for both the visual and the auditory inhibition groups. There should have been a visual as well as an auditory inhibition group, for whom food was signaled only by the sounds produced when the hopper operated, included for comparison.

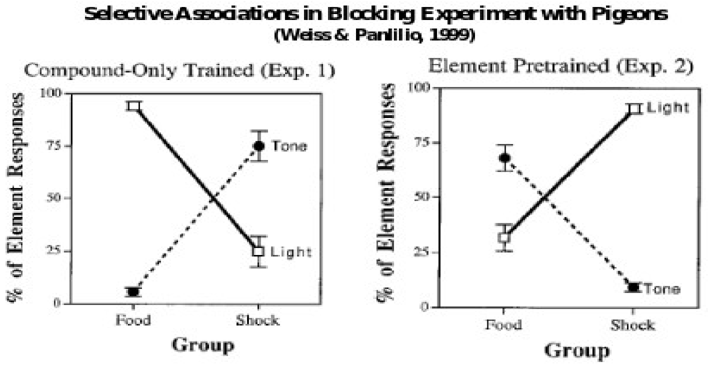

***Figure 12***. A direct comparison of the selective association interaction profiles produced by Weiss and Panlilio's (1999) compound-only trained and those pretrained with the biologically-contingency-disadvantaged element-prior to compound-stimulus training. See captions of Figures 10 and 11 for explanation. Adapted from Weiss and Panlilio (1999).

## Discussion

The results of the single incentive studies presented in this article consistently supported the hypothesis that selective associations are the product of an hedonic state, relatively positive or negative, induced by the auditory-visual compound stimulus relative to its absence. The hedonic effects of the compound were conditioned through discrimination training on two-component training baselines. This account is essentially functional in nature, describing the conditioned states that appear to be necessary to produce these selective associations. However, the hedonic model does not say anything about how this might have developed from an evolutionary perspective. Although any evolutionary *explanation* of how/why selective associations developed would have to be speculative in nature, they could be informative and therefore will be sketched below for completeness.

### Proposed Explanations of Selective Association

Hypothetical neurological substrates selected for in evolution have been a popular account of predispositions for selective associations (Garcia et al., 1972; LoLordo, 1979). Although it has strong face validity, over 30 years ago Domjan and Galef (1983) contended that this evolutionary-ethological account makes few clear predictions, and has essentially led to a *cataloguing* of constraints instead of an integrative theoretical framework. It can be invoked as the origin of any biological constraint, but it does not support one possible mechanism over another. Therefore, it brings us no closer to an understanding of how this phenomenon is mediated. Even if a constraint could be proven to be the result of a unique evolutionary adaptation, an evolutionary account can never be considered a complete explanation. It is easy to presume that all examples of learning have been influenced by evolution, but this line of reasoning becomes circular when it is used as a post-hoc explanation for every constraint on learning that turns up. However, the hedonic model of selective associations does relate it to the incentive-motive process that thereby integrates it with a wide variety of phenomena related to this mechanism such as choice behavior, behavioral contrast, conditioned preference and appetitive-aversive interactions.

Jacobs and LoLordo (1977, 1980) favored an ethological account of their results based on the suggestion that rats tend to respond to the sound of a *predator* by running towards a dark hole. If the sound of a predator is considered *hedonically negative*, this is consistent with the results of the experiments presented above (Figures 4 and 6) that broke the confound between conditioned hedonic state and class of reinforcer in the traditional appetitive-aversive selective association studies with pigeons (Foree & LoLordo, 1973) and with rats (Schindler & Weiss, 1982). The hedonic hypothesis is consistent with Jacobs and LoLordo's (1977) results where (1) auditory stimuli were most effective in a transfer-of-control design when they signaled impending shock (a hedonically negative condition that would be non-preferred), and (2) least effective when the signaled safety from shock (a hedonically positive condition that would be preferred).

Animals tend to have biases to learn certain contingencies from the time they are born. Knowing the nature of these biases does not necessarily allow us to make strong predictions about selective associations later in the animal's life. For example, newly-hatched chicks use auditory, visual, gustatory and tactile stimuli in different and specific ways to *learn to recognize food* during a critical period in their development (Hogan, 1973). These do seem to have been shaped by earlier experience, and their effects on subsequent learning are far from clear. An examination of Hogan's observation does not seem lead in any obvious way to a prediction of the selective associations observed in pigeons when TL was food- or shock-related over groups (Foree & LoLordo's, 1973; Panlilio & Weiss, 1999) or the single-incentive generated selective associations with pigeons discussed in this article (Panlilio & Weiss, 2005).

One alternative explanation of selective associations involves learning occurring before experimental training (Domjan, 1973). That selective associations can be reversed (see Figure 8) and blocked (Figures 9 and 11) is consistent with that — and is not inconsistent with there being a biological predisposition operating here related to an hedonic mechanism. In any event, unless this pre-experimental learning is known, it has little predictive value. Shettleworth (1972b) demonstrated selective associations in very young animals. That suggests even if previous experiences are necessary for the formation of these effects, they happen so rapidly and regularly that it is hard not to conclude even such early associations are selective.

Another explanation of selective associations involves differences in the unconditioned responses to various stimuli. It contends that if the unconditioned effects of a stimulus are identical, similar or antagonistic to those of the reinforcer they are paired with, this could directly affect subsequent learning. One manifestation of this kind of an effect occurs when the stimulus and reinforcer are physically similar (Testa, 1973). For example, a stimulus with a similar location and quality as the reinforcer it is paired with is more effective than one that is less similar. Stimuli also produce more evidence of learning in a second-order conditioning procedure if they are of the same modality (rats) or visual (pigeons) dimension than if they are different (Rescorla & Furrow, 1977).

Although this could be one way of producing selective associations, this kind of explanation is no more definitive or clear than the ethological and previous experience explanation if the similarities are not intentionally set up, and ultimately parametrically tested, by the experimenter. For example, a post-hoc analysis of Foree and LoLordo's (1973) experiment might suggest that the selective association they reported is due to the fact that visual stimuli have unconditioned effects in pigeons that are somehow more similar to those elicited by food than those elicited by shock. But in addition to the results of their experiment there needs to independent evidence to support this hypothesis. In addition, it is not that easily applied to the appetitive-aversive selective associations reported in rats plus probably can not be applied to the single-incentive selective associations described in this article for both rats and pigeons. In that regard, consider the situations where *exactly* the same shock avoidance contingency operated in TL — but when its conditioning context made it a TL+ visual control dominated and when its context made it a TL- audio control dominated — for both rats (Weiss et al., 1993b) and pigeons (Panlilio & Weiss, 2005). Therefore, a mechanism that involves any kind of similarity relation between the stimulus and the reinforcer does not seem to apply here.

Evolution is presumably involved in the formation of the biological bases of all behavior. Therefore, reiterating this does little to advance our understanding of any specific behavioral phenomenon. Stimulus similarity and previous experience might certainly influence the formation of selective association but there is no systematic evidence that they are basically responsible for the phenomena. Therefore, these explanations are either untestable, post-hoc, inadequate or all three. Weiss et al.'s (1993a, 1993b) hedonic-state model does not explain the origin of selective associations. But it does propose, and has empirically supported, the conditions necessary to produce them that can be operationally defined by contingency-produced preference between the auditory-visual compound condition and its absence.

### Selective Associations in Non-traditional Learning Paradigms

Before concluding, the author wants to make clear that the hedonic model of selective associations cannot be applied to all instances of selective associations. As it stands, this model predicts selective associations only in situations where (1) conditions created a relative hedonically positive exteroceptive audio-visual compound in one group, and a relative hedonically negative compound in the other, with (2) what might be considered traditional conditioning and learning paradigms. In those studies that compared illness-inducing treatments to shock as reinforcers (e.g., Garcia & Koelling, 1966; Garcia, McGowan, Ervin, & Koelling, 1969; Wilcoxon, Dragoin, & Kral, 1971; Domjan & Wilson, 1972), both situations were aversive and therefore non-preferred. In addition, with the compound stimulus bright, noisy and tasty water, attentional control to exteroceptive cues, such as tones and lights, were not compared to each other. Moreover, as was mentioned earlier in this article taste-aversion learning has special properties that distinguish it from most traditional conditioning and learning situations. Therefore, the hedonic model, although successful in every traditional learning situation in which it has been tested, with rats as well as pigeons, might not apply to these special studies.

## Conclusion

Within the rather wide range of studies employing traditional learning procedures with audio-visual compounds reviewed here, the hedonic model was consistently supported. Where conditions were such that the compound stimulus would be clearly preferred to its absence by one group and non-preferred by the other, it has held up to extensive and rigorous testing. The hedonic model handled the interactions reported in classical, discrete-trial instrumental and free-operant operant studies — some employing only appetitive, some only aversive and others appetitive and aversive reinforcers over groups. Moreover, the hedonic model relates the underlying processes responsible for selective associations here to the same conditions responsible for choice behavior in general, conditioned preference, appetitive-aversive interactions, behavioral contrast and incentive-motivation (deVilliers, 1977; Dickinson & Dearing, 1979; Herrnstein, 1970; Weiss & Schindler, 1989; Weiss, Thomas, & Weissman, 1996; Weiss, 2014a, 2014b). That is a substantial scientific integration![4]

This hedonic model views the organism as a comparator of the different situations it encounters. Most convincing in that regard are the experiments described above with rats in Figure 6 (Weiss et al., 1993b) and pigeons in Figure 7, left frame, (Panlilio & Weiss, 2005), where exactly the same free-operant shock avoidance contingency both (1) lowered “fear” and produced predominant visual control, and (2) increased “fear” and produced predominant auditory control. The hedonic state induced when a subject entered the TL compound was determined by the conditions it experienced when the compound stimulus was absent (either noncontingent shock plus punishment or safety, respectively) which created TL’s *conditioning context*. With the organism here a comparator of different conditions it encounters within its environment, it is clearly operating on a much higher level of processing than has here-to-fore been considered with biological-constraints-on-learning. A physical description of the situation encountered in TL, free-operant avoidance of shock, could not itself account for the selective association here. This and related appetitive-only research in Figures 4 (Weiss et al., 1993a) and 7, center frame (Panlilio & Weiss, 2005) demonstrate that it is not the particulars of the physical situation that are central to the hedonic side of psychological science.

We also saw that after a selective-association was established, switching contingencies (i.e., TL+ to TL- and vice-versa) completely reversed the effect (Schindler & Weiss, 1982; Panlilio & Weiss, 1993). This indicates that it is the *current* hedonic psychological state that the compound induces, relatively positive or negative, that determines the degree to which the compound’s visual or auditory elements exert control over behavior. Surprisingly, past hedonics states experienced in the compound didn’t seem to matter. In addition, selective associations were not only “blocked” in rats and pigeons pretrained with the biologically-contingency-disadvantaged stimulus element before compound-stimulus training. Such pretraining actually reversed the selective associations (Schindler & Weiss, 1985; Weiss & Panlilio, 1999). This demonstrated that there are situations where appropriately applied contingencies of reinforcement can not only *neutralize* a biological-constraint-on-learning but actually *overwhelm* (i.e., reverse) it.

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[4] It should be appreciated that in addition to “... [relative] reinforcement probability, factors such as schedule requirements, delay of reinforcement, reinforcement magnitude, effort, [plus] reinforcement predictability or periodicity can influence reinforcement value [and resulting incentive motivation associated with an $S^D$] in the instrumental situation. Determining the [relative] reinforcement value acquired by a schedule component requires a...[behavioral]...measure reflecting the organisms’ integration of all these influences. Component preference could serve this function... (Weiss, 1978, p 363). Adaptation level (Helson, 1974) could also be relevant here.

It should be abundantly clear by now that (1) the psychological states resulting from the interaction of the behaving individual with its physical environment are our primary concern here, and (2) these states can be (and possibly usually are) a product of the totality of the reinforcement contingencies operating in the behaving organism's environment rather than its *natural* reaction to the physical events experienced therein. The research program presented here substantiating that an hedonic mechanism was responsible for the biological-constraint-on-learning identified as *selective associations* supports this. It has also been supported by the instrumentally-derived incentive-motivational functions produced by Weiss (2014a, 2014b) and therefore the broad spectrum of behaviors related to incentive-motivational states mentioned earlier in this article.

The wide variety of experimental manipulations described herein that were employed to better our understanding of selective associations was applied to rats as well as pigeons – and each produced comparable results. We have here very different avian and mammalian species with, additionally, different dominant sensory systems — visual and auditory, respectively. Therefore, the many similarities in attentional control over a wide variety of situations suggest that we could be contacting here rather common, basic constraints with a long evolutionary history.

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## References

Anger, D. (1963). The role of temporal discriminations in the reinforcement of Sidman avoidance behavior. *Journal of the Experimental Analysis of Behavior, 6*, 477-506.

Azrin, N. H. (1959). A technique for delivering shock in pigeons. *Journal of the Experimental Analysis of Behavior, 2*, 161-163.

Badia, P., & Culbertson, S. (1972). The relative aversiveness of signaled versus unsignalled escapable and inescapable shock. *Journal of the Experimental Analysis of Behavior, 17*, 463-471.

Bailey, R. E., & Gillaspy Jr., J. A. (2005). Operant psychology goes to the fair: Marian and Keller Breland in the popular press, 1947-1966. *The Behavior Analyst, 28*, 143-159.

Bouton, M. E. (2004). Context and behavioral processes in extinction. *Learning and Memory, 11*, 485–494.

Breland, K., & Breland, M. (1961). The misbehavior of organisms. *American Psychologist*, *16*, 661-664.

DeVilliers, P. (1977). Choice in concurrent schedules and a quantitative formulation ofthe law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp.233-287). Englewood Cliffs, NJ: Prentice-Hall.

Dickinson, A., & Dearing, M. F. (1979). Appetitive-aversive interactions and inhibitory processes. In A. Dickinson and R. A. Boakes (Eds.), *Mechanisms of Animal Learning and Motivation: A Memorial Volume to Jerzy Konorski* (pp. 203-232). Hillsdale, NJ: Erlbaum.

Dinsmoor, J. A. (1983). Observing and conditioned reinforcement. *Behavior and Brain Sciences*, *6*, 693-728.

Dinsmoor, J. A., Bowe, C. A., Green, L., & Hansen, J. (1988). Information on response requirements compared with information on food density as a reinforcer of observing in pigeons. *Journal of the Experimental Analysis of Behavior*, *49*, 229-237.

Dinsmoor, J. A., Lee, D. M., & Brown, M. M. (1986). Escape from serial stimuli leading to food. *Journal of the Experimental Analysis of Behavior*, *46*, 259-279.

Domjan, M. (1983). Biological constraints on instrumental and classical conditioning: Implications for general process theory. In G. H. Bower (Ed.), *The Psychology of learning and motivation*, (Vol. 17, pp. 215- 277). New York, NY: Academic Press.

Domjan, M., & Galef, B. G. (1983. Biological constraints on instrumental and classical conditioning: Retrospect and prospect. *Animal Learning and Behavior*, *11*, 151-161.

Domjan, M., & Wilson, N. E. (1972). Specificity of cue to consequence in aversion learning in the rat. *Psychonomic Science*, *26*, 143-145.

Duncan, E., & Fantino, E. (1972). The psychological distance to reward. *Journal of the Experimental Analysis of Behavior*, *18,* 23-34.

Emurian, H. H., and Weiss, S. J. (1972). Compounding discriminative stimuli controlling free-operant avoidance. *Journal of the Experimental Analysis of Behavior*, *17*, 249-256.

Foree, D. D., & LoLordo, V. M. (1973). Attention in the pigeon: Differential effects of food-getting versus shock avoidance procedures. *Journal of Comparative and Physiological Psychology*, *85*, 551-558.

Foree, D. D., & LoLordo, V. M. (1975). Stimulus-reinforce interactions in the pigeon: The role of electric shock and the avoidance contingency. *Journal of Experimental Psychology: Animal Behavior Processes*, *1*, 39-46.

Garcia, J., & Koelling, *R.* A. (1966). Relation of cue to consequence in avoidance learning. *Psychonomic Science*, *4*, 123-124.

Garcia, J., McGowan, B. K., Ervin, P. R., & Koelling, R. A. (1968). Cues: Their relative effectiveness as a function of the reinforcer. *Science*, *160,* 794 -795.

Garcia, J., McGowan, B. K., & Green, K. F. (1972). Biological constraints on conditioning. In A. H . Black & W. F. Prokasy (Eds*.), Classical conditioning II: Current theory and research* (pp. 3-63). New York, NY: Appleton-Century-Crofts.

Helson, H. (1974). *Adaptation level theory*. New York, NY: Harper & Row.

Hendry, D. P. (1967). Conditioned inhibition of conditioned suppression. *Psychonomic Science*, *9,* 261-262.

Herrnstein, R. J. (1970). On the law of effect. *Journal of the Experimental Analysis of Behavior*, *13*, 243-266.

Holz, W., Azrin, N, & Ayllon, R. (1963). Elimination of behavior of mental patients by response-produced extinction. *Journal of the Experimental Analysis of Behavior, 6*, 407-412.

Hinde, R. A., & Stevenson-Hinde, J. (1973). *Constraints on learning*. London, UK: Academic Press.

Hogan, J. A. (1973). How young chicks learn to recognize food. In R. A. Hinde & J. Stevenson-Hinde (Eds.), *Constraints on learning* (pp.119-139**)**. London, UK: Academic Press.

Jacobs, W. J., & LoLordo, V. M. (1977). The sensory basis of avoidance responding in the rat. *Learning and Motivation*, *8*, 448-466.

Jacobs, W. J., & LoLordo, V. M. (1980). Constraints on Pavlovian aversive conditioning: Implications for avoidance learning in the rat. *Learning and Motivation*, *11*, 427-455.

Kamin, L. J. (1969). Predictability, surprise, and conditioning. In B. A. Campbell & R. N. Church (Eds.), *Punishment and aversive behavior*. New York, NY: Appleton-Century-Crofts.

Kearns, D. N., & Weiss, S. J. (2005). Reinstatement of a food-maintained operant response by compounding discriminative stimuli. *Behavior Processes*, *70*, 194-202.

Killeen, P. (2014). Pavlov + Skinner = Premack. *International Journal of Comparative Psychology*, *4*, 544-568.

Konorski, J. (1967). *Integrative activity of the brain*. Chicago, IL: University of Chicago Press.

LoLordo, V. M. (1969). Positive conditioned reinforcement from aversive situations. *Psychological Bulletin*, *72*, 193-203.

LoLordo, V. M. (1979). Selective associations. In A. Dickinson and R. A. Boakes (Eds.), *Mechanisms of animal learning and motivation*: *Memorial Volume to Jerzy Konorski* (pp. 367-398). Hillsdale, NJ: Erlbaum.

LoLordo, V. M., Jacobs, W. J., & Foree, D. D. (1982). Failure to block control by a relevant stimulus. *Animal Learning and Behavior*, *10,* 183-193.

Mackintosh, N. J. (1974). *The Psychology of Animal Learning*. London, UK: Academic Press.

Panlilio, L. V., & Weiss, S. J. (1993). Reversibility of single-incentive selective associations. *Journal of the Experimental Analysis of Behavior*, *60*, 85-104.

Panlilio, L. V., & Weiss, S. J. (2005). Sensory modality and stimulus control in the pigeon: Cross-species generality of single-incentive selective association effects. *Learning & Motivation*, *36*, 408-424.

Reed-Elder, C., & LoLordo, V. M. (1985). Visual Dominance in inhibitory conditioning in the pigeon. *Learning and Motivation*, *16*, 158-172.

Rescorla, R. A., & Furrow, D. R. (1977). Stimulus similarity as a determinant of Pavlovian conditioning. *Journal of Experimental Psychology: Animal Behavior Processes*, *3,* 203-215.

Rescorla R. A., & Heth, C. D. (1975). Reinstatement of fear to an extinguished conditioned stimulus. *Journal of Experimental Psychology: Animal Behavior Processes*, *1*, 88-96.

Rescorla, R. A., & Holland, P. C. (1976). Some behavioral approaches to the study of learning. In M. R. Rosenzweig & E. L. Bennett (Eds.), *Neural mechanisms of learning and memory,* Cambridge, MA: MIT Press.

Revusky, S. H., & Garcia, J. (1970). Learned associations over long delays. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 4). New York, NY: Academic Press.

Schindler, C. W., & Weiss, S. J. (1982). The influence of positive and negativereinforcement on selective attention in the rat. *Learning and Motivation*, *13*, 304-323.

Schindler, C. W., & Weiss, S. J. (1985). Modification of a stimulus-reinforcer interaction by blocking. *Behavioural Processes*, *11*, 123-130.

Sidman, M. (1953). Two temporal parameters of the maintenance of avoidance behavior by the white rat. *Journal of Comparative and Physiological Psychology*, *46*, 253-261.

Sidman, M. (1960). *Tactics of scientific research*. New York, NY: Basic Books.

Seligman, M. E. P., & Hager, J. L. (1972). *Biological boundaries of learning*. New York, NY: Appleton-Century-Crofts.

Shapiro, E. L., Jacobs, W. J., & LoLordo, V. M. (1980). Stimulus-reinforcer interactions in Pavlovian conditioning of pigeons. *Animal Learning & Behavior*, *8*, 586-594.

Shettleworth, S. J. (1972a). Constraints on learning. In R.A. Hinde and E. Shaw (Eds.), *Advances in the study of behavior* (Vol. 4, pp. 1-68). New York, NY: Academic Press.

Shettleworth, S. J. (1972b). Stimulus relevance in the control of drinking and conditioned fear in domestic chicks (*Gallus gallus*). *Journal of Comparative and Physiological Psychology*, *80,* 175-198.

Testa, T. J. (1975). Effects of similarity of location temporal intensity pattern of conditioned and unconditioned stimuli on the acquisition of conditioned suppression in the rat. *Journal of Experimental Psychology: Animal Behavior Processes*, *1*, 114-121.

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

Timberlake, W., Wahl, G., & King D. (1982). Stimulus and response contingencies in the misbehavior of rats. *Journal of Experimental Psychology: Animal Behavior Processes, 8*, 62-85.

Verhave, T. (1962). The functional properties of time-out from an avoidance schedule. *Journal of the Experimental Analysis Behavior*, *5*, 391-422.

Weiss, S. J. (1976). Stimulus control of free operant avoidance: The contribution of response rate and incentive relations between multiple schedule components. *Learning and Motivation*, *7*, 477-516.

Weiss, S. J. (1977). The isolation of stimulus=reinforcer associations established with multiple schedules. *Animal Learning and Behavior*, *5*, 421-429.

Weiss, S. J. (2014a). Instrumental and classical conditioning: Intersections, interactions and stimulus control. In F. K. McSweeney & E. S. Murphy (Eds.), *The Wiley Blackwell handbook* *of operant and classical conditioning* (pp. 417-451). Chichester, Sussex: John Wiley & Sons Ltd.

Weiss, S. J. (2014b). The instrumentally derived incentive-motivational function. *International Journal of Comparative Psychology*, *27*, 598-613.

Weiss, S. J., Kearns, D., Cohn, S., Schindler, C. W., & Panlilio, L. V. (2005). Cocaine and selective associations: Investigations into a biological constraint on learning with drug self-administration and shock-avoidance as reinforcers. *International Journal of Comparative Psychology, 18*, 112-125.

Weiss, S. J., Panlilio, L. V., & Schindler, C. W. (1993a). Selective associations produced solely with appetitive contingencies: The stimulus-reinforcer interaction revisited. *Journal of the Experimental Analysis of Behavior*, *59*, 309-322.

Weiss, S. J., Panlilio, L. V., & Schindler, C. W. (1993b). Single-incentive selective associations produced solely as a function of compound-stimulus conditioning context. *Journal of Experimental Psychology: Animal Behavior Processes*, *19*, 284-294.

Wilcoxon, H. C., Dragoin, W. B., & Kral, P. A. (1971). Illness-induced aversions in rat and quail: Relative salience of visual and gustatory cues. *Science*, *171*, 826-828.

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