Title
The Instrumentally-Derived Incentive-Motivational Function

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The Instrumentally Derived Incentive-Motivational Function

Stanley J. Weiss
American University, USA

Through differential reinforcement, a discriminative stimulus (S^D) acquires two properties. The operant contingency is responsible for the S^Ds response-discriminative property. However, as stimulus control develops an S^D also acquires *incentive-motivational* properties through its association with reinforcement changes. A systematic series of experiments breaks the co-variation of response and reinforcement rates found in most discriminative operant situations. In three groups, S^Ds (a tone and a light) each occasioned rats' steady moderate lever pressing that ceased when neither S^D was present. With different multi-component operant contingencies, probability of reinforcement (food) during these S^Ds, relative to when both were off, was systematically manipulated over groups to make the S^Ds incentive-motivationally excitatory, neutral or inhibitory. Although behaviorally indistinguishable in training, a stimulus-compounding assay revealed that tone-plus-light tripled the response rate in the incentive-excitatory group, doubled rate in the incentive-neutral group and didn't increase rate in the incentive-inhibitory group – producing the instrumentally derived incentive-motivational function for the first time. An instrumentally-derived aversive incentive-motivational function is also produced. These results are discussed in the context of two-process learning theory, transfer-of-control research, and how response-discriminative and incentive-motivational properties of an S^D contribute to stimulus control of behavior. The functions support the contention that *in nature* environmental conditions being differentially correlated with reinforcement could be responsible for most *classical conditioning* and resulting incentive-motive states.

In nature, through differential reinforcement environmental cues come to occasion the behavior an organism needs to engage in to produce particular outcomes. For example, pushing on a closed door will not open it, but doing so after the doorknob has been turned will. So, through differential reinforcement a closed door becomes a discriminative stimulus (S^D) for turning the door knob because pushing (or pulling) the door without doing so will not be reinforced by it opening (e.g., Thorndike, 1898). There are few situations, except when we are actually sleeping, perhaps (but we don't fall out of bed!), when our behavior is not under such *stimulus control* produced by differential reinforcement. It is so omnipresent that we come to take it for granted – just as we do for our most complex metabolic processes.

Another, more complex, example of differential reinforcement is the sequence of behaviors engaged in when starting a car. That entails placing the key in the ignition, turning it in the proper direction for just the appropriate amount of time (with our foot on the brake), then putting the transmission in the appropriate gear, etc., etc. A more social, interpersonal, example of differential reinforcement producing stimulus control of verbal behavior is the situation in which a speaker is likely to get an answer to a question only when he/she has a *prepared* listener's attention (e.g., Skinner, 1957).

Correspondence regarding this article should be sent to Dr. Weiss, American University, Washington, USA (Email: sweiss@american.edu).

The multiple schedule described by Ferster and Skinner (1957) models such differential reinforcement in the laboratory. On a multiple schedule, different reinforcement contingencies operate during different discriminative stimuli (S^Ds). The situation where a rat's lever pressing intermittently produces food only when a tone is on, but not when it is off, is an example of a two-component multiple schedule – although multiple schedules usually contain more than two components. This relationship is represented schematically by the three-term contingency: S^D • R -› S^r. It symbolizes that a behavior (R), here lever pressing, emitted in the presence of a discriminative stimulus (S^D), here tone-on, will produce a reinforcer (S^r), here food – while R will not produce the S^r when the tone is off because that condition signals an extinction period (S^A). Such differential reinforcement creates operant *stimulus control* through which an S^D comes to occasion a particular behavior that represents the response-discriminative property of that S^D.

The differential correlation of the S^D with reinforcement, a *by-product* of this *emergent* stimulus control of the subject's behavior, inherently produces a Pavlovian type association because food is presented during the S^D (tone) but not when the S^D is absent (Pavlov, 1927). This implicit associative arrangement that can be identified within most multi-component operant schedules can produce incentive-motivational effects that energize behavior (e.g., Brown 1961; Logan, 1960; Weiss, 1978; Weiss, Thomas, & Weissman, 1996). Trapold and Overmier (1972) represented this *embeddedness* schematically with the S-R-S^r notation. This three-term contingency includes within it the operant (R-S^r) and classical (S-S^r) contingencies responsible for the S^Ds response-discriminative and incentive-motivational properties, respectively, plus the resulting environmental operant control (S-R).
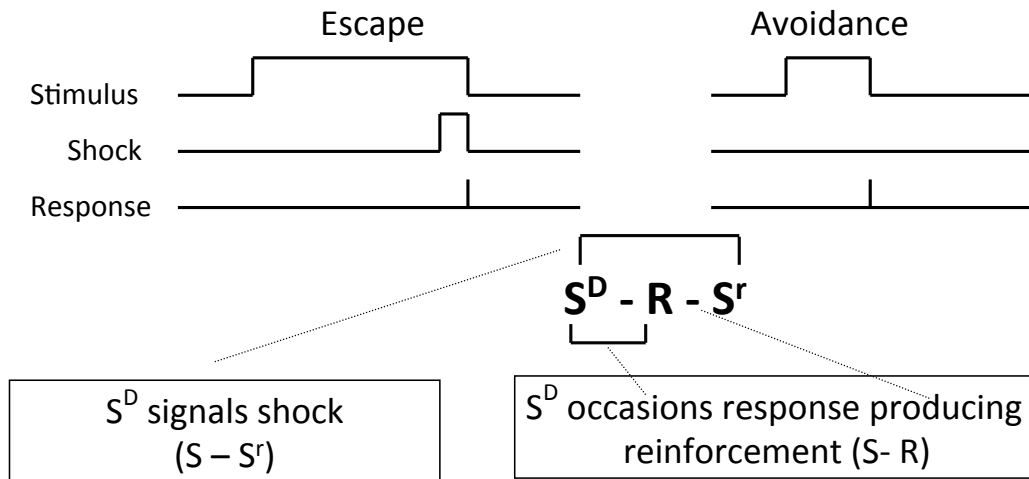
The two-process learning theory (e.g., Bindra, 1972; Gray, 1975; Mowrer, 1947; Rescorla & Solomon, 1967; Schlosberg, 1937; Weiss, 1978, 2014; Weiss et al., 1996) has been concerned with the dynamics of this situation for some time. For example, Mowrer (1947) observed that classical contingencies were embedded in the discriminated-operant avoidance paradigm. He postulated two-process learning theory because in such situations "…conditioning of the visceral-vascular, or `diffuse,' responses takes place first and that the accompanying emotional state provides the motivation, or problem, which produces the subsequently observed skeletal, or `precise, adaptive,' reactions" (p. 127).

Therefore, the temporal dynamics of this situation would create stimuli that became motivational mediators (through the embedded classical contingency between the warning stimulus and the shock) as well as discriminative in nature (through the operant contingency when a response is negatively reinforced by terminating the warning stimulus). This is schematically represented in Figure 1. That better avoidance conditioning was obtained if the avoidance response immediately terminated the warning stimulus than when it was of a fixed duration supported this position (Mowrer & Lamoreoux, 1942).

Two-process learning theory is being applied here by utilizing the two contingency-related properties acquired by a discriminative stimulus (S^D) when determining its stimulus control. To reiterate, the S^D's *discriminative-response* (S-R) property is the behavior change it occasions. That is a product of what the operant contingency requires to produce the reinforcer ultimately maintaining the operant behavior. In comparison, the *incentive-motive* (S-S^r) property of an S^D is acquired through the reinforcement differences that come to exist between components of multi-component discriminative operant baselines – a classical conditioning arrangement more subtle than that presented in Figure 1. These reinforcement differences between S^D-identified schedule components (1) create the implicit classical contingencies *naturally embedded* within the operant baselines, and (2) are responsible for the excitatory and inhibitory incentive-motive properties acquired by an S^D.[1]

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[1] However, 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

Schematic of Mowrer's (1947) Two-Factor Theory

Escape   **Avoidance**

Stimulus

Shock

Response

$$S^D - R - S^r$$

| S^D signals shock $(S - S^r)$ | S^D occasions response producing reinforcement (S- R) |

- The *incentive-motive* process is a product of the embedded S-S^r contingency.

- The *discriminative response* process (S-R) is generated because the operant is only effective in the presence of particular stimuli (differential reinforcement).

Figure 1. *A schematic representation of Mower's (1947) two-factor theory.* Note that when a subject is first placed in this discriminated-operant situation a signaled shock is presented that requires an operant response to terminate it. Through this functional classical association, the signal becomes a conditioned aversive stimulus that elicits fear. Subsequently, an operant emitted during the warning stimulus terminates it and is therefore negatively reinforced by removal of the fear-eliciting stimulus. Thus, the warning stimulus produces the incentive-motive state (fear) that energizes the operant that is reinforced by termination of the warning stimulus and resulting fear. This can be extended to operant differential reinforcement situations more generally. Therein, one sees that by becoming differentially associated with reinforcement as operant stimulus control develops, a discriminative stimulus (S^D) acquires incentive-motive as well as discriminative properties.

      Unfortunately for functional analysis, the discriminative-response and incentive-motivational properties acquired by an S^D co-vary in most operant situations (Shettleworth & Nevin, 1965). This makes the contribution of each process to resulting stimulus control elusive and difficult to appreciate. Weiss' three component multiple schedule training paradigm clearly illustrates this co-variation (1971, Exp. 2). In that experiment, rats' lever pressing produced food on a variable-interval (VI) schedule when either the tone or light S^D was present. However, food was unavailable (extinction) during periods following these S^Ds when neither the tone nor the light was on (hereafter referred to as the $\overline{TL}$ condition). Therefore, the tone and light *each*: (1) become discriminative for the lever pressing (S-R↑) that was required for reinforcement, and (2) acquired excitatory incentive-motivational properties (S-S^r↑) through their association with an increase in the probability of receiving food -- from 0% in $\overline{TL}$ to nearly 100% when the tone or light was present.

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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).

Training continued until the response rates during tone and during light were steady and reliably at least 10 times the rate during $\overline{\text{TL}}$. Then, a stimulus-compounding test was administered wherein the tone and light were presented *simultaneously* (T+L) for the *first* time. This test consisted of block-randomized, one-minute presentations of tone, light and T+L – each separated by one-minute of $\overline{\text{TL}}$. It was conducted in extinction to preclude extraneous effects of reinforcer-related behaviors elicited or occasioned by feeder-operation or food from influencing test results.

On this stimulus-compounding test, the T+L compound controlled about three-times the response rate of tone or light presented alone (Figure 2). Regrettably, looking only at this experiment, the process(es) responsible for this three-fold response increase are indeterminate because the discriminative-response (S-R) and incentive-motivational (S-S^r) properties established to the compounded S^{D}s co-varied – both increasing, S-S^r↑ and S-S^r↑, respectively. The enhanced responding to T+L could be due to the fact that, compared to tone or light alone, T+L contains two stimuli that (1) signal the food (activating the incentive-motivational process, S-S^r↑), (2) occasion a response-rate increase (activating the discriminative-response process, S-S^r↑), or (3) some combination of the two. As mentioned previously, this confound is common in most behavioral situations (Shettleworth & Nevin, 1965). The two properties must be dissociated if we are to understand the process(es) responsible for the three-fold increase in responding T+L produced above. Such dissociation would help us better understand how the classically-conditioned and operantly-conditioned properties of the training stimuli (S^{D}s) intersect and interrelate.
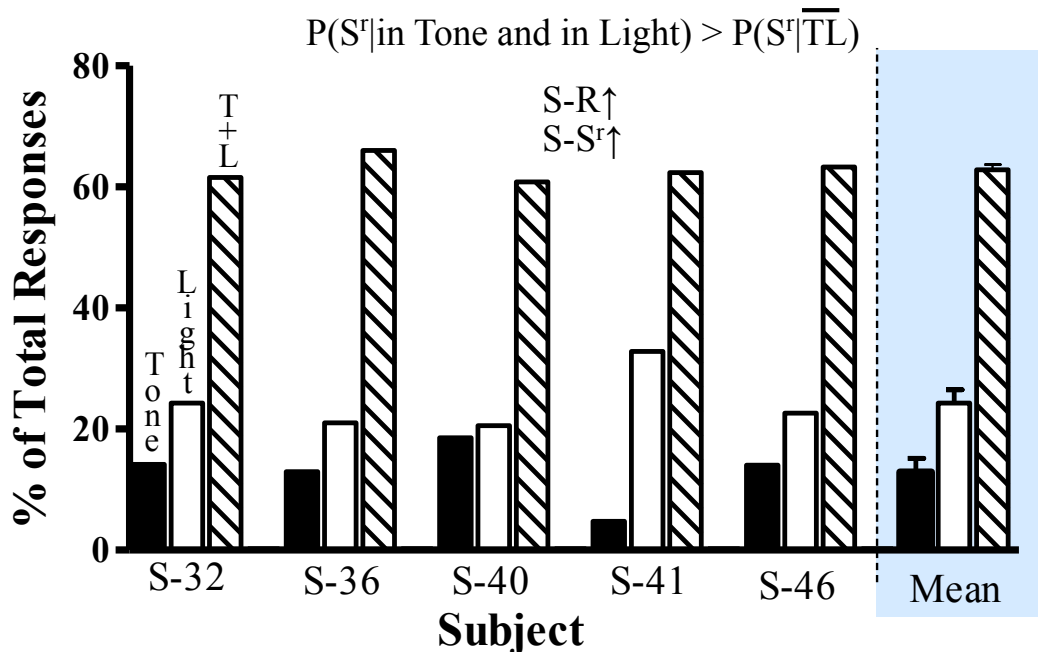

Figure 2. *Results of Weiss' (1971, Exp. 2) stimulus-compounding test.* Multiple-schedule trained rats earned food in tone and in light S^{D}s, but not their absence ($\overline{\text{TL}}$). Tone-plus-light was presented for the first time on this test that was conducted in extinction. Multiple-schedule trained rats earned food during tone and during light S^{D}s, but not during their absence $\overline{\text{TL}}$. Tone-plus-light was presented for the first time on this test that was conducted in extinction. Note the consistency over subjects. Adapted from Weiss (1971), Figure 6.

Producing the Instrumentally-Derived Incentive-Motivational Function: Appetitive

The confounded S-R and S-S^r properties of the S^{D}s described above were broken by employing operant schedules that held the discriminative-response property of the S^{D}s comparable over three groups while systematically manipulating their incentive-motive property between groups (Weiss, 1969; Weiss, 1971, Exp. 2; Weiss and Van Ost, 1974). In all three groups the tone and the light S^{D}s *each* occasioned a steady, moderate lever-press response (S-R↑) that was maintained by food. However, each group had a different embedded classical contingency related to these S^{D}s that produced incentive-motivational properties that were excitatory (S-S^r↑), neutral (S-S^r=) or inhibitory (S-S^r↓). The dual properties that these relationships would establish to the tone and to the light S^{D}s can be symbolically represented for the three groups as:

Group A: S-R↑, S-S^r ↑
Group B: S-R↑, S-S^r=
Group C: S-R↑, S-S^r↓

Here, and throughout the present article, the discriminative-response as well as the incentive-motivational properties established to tone and to light S^{D}s are described *relative* to what is happening in $\overline{TL}$.

Brown (1961) and Logan and Wagner (1965) proposed that a subject's preference between goal objects indicates which has the greater incentive and reinforcement value. With positive reinforcement, the preferred condition possesses the greater excitatory-incentive value because one is working to produce an *attractive* event. As described above (Weiss, 1971, Exp. 2), in Group A's conditions the tone and the light were each differentially correlated with food (relative to $\overline{TL}$ and thereby became excitatory CS's through this S-S^r↑ relationship. Therefore, the tone and light components would be preferred over $\overline{TL}$ (Holz, Azrin, & Ayllon, 1963).

Briefly, the three-component operant training schedules of Groups B and C (Weiss, 1971, Exp. 2; Weiss and Van Ost, 1974) were arranged as follows. For Group B, lever-pressing produced food on a VI schedule when the tone or light were present, as for Group A described above. But, during $\overline{TL}$ food was delivered on a differential-reinforcement-of-other-behavior (DRO) schedule in which food was received as long as lever-pressing did *not* occur for a specified amount of time. With this multiple VI DRO schedule, lever-pressing in $\overline{TL}$ was essentially eliminated while, since probability of food in tone, light and $\overline{TL}$ were comparable, differential incentive-motivational properties should not be conditioned to tone or light relative to $\overline{TL}$.

Group C was trained on a chained VI DRO schedule where lever-pressing on a VI schedule during tone or light components caused the chain to progress to the $\overline{TL}$ component where food was presented for not responding (DRO). After a few minutes, $\overline{TL}$ terminated – with a tone or a light component equally likely to appear. Here, food probability was zero during tone or light, but close to 100% during $\overline{TL}$. This would establish inhibitory appetitive-incentive-motivational properties (S-S^r↓) to these S^{D}s, relative to $\overline{TL}$, with these S^{D}s the non-preferred components (Duncan & Fantino, 1972). (On this chained schedule, the rats were, in fact, always working to remove themselves from these S^{D}s.) Compare that to Group B, where with food received in all three components of the training schedule, tone, light and $\overline{TL}$ would be about equal in a preference test (Herrnstein, 1964). This supports that the appetitive incentive-motivational properties conditioned to the tone and to the light S^{D}s systematically varied across these three groups -- from excitatory (S-S^r↑) in Group A through neutral (S-S^r=) in Group B to inhibitory (S-S^r↓) in Group C.

Figure 3 displays representative cumulative records of subjects from Group C (chain VI DRO) and Group B (multiple VI DRO). (On each schedule, the VI component was signaled by tone or by light equally often.) With respect to the lever response, these subjects are behaviorally comparable, responding at steady-moderate rates during tone and during light (S-R↑) but not responding during $\overline{TL}$. Except for hatch-marks showing that S-203 received food during tone, light and $\overline{TL}$, while S-201 received food only during $\overline{TL}$, these records are *indistinguishable*. (To ensure that chain- and multiple-schedule-trained rats were comparably exposed to tone, light and $\overline{TL}$ components, respectively, Weiss and Van Ost (1974) *yoked* pairs of rats with respect to these durations.)
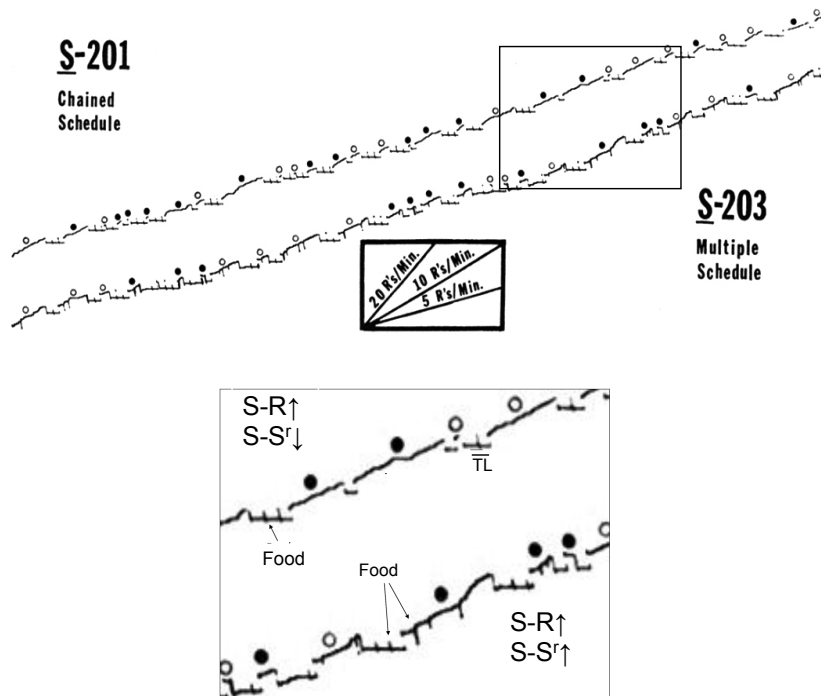

Figure 3. *Cumulative records of chain-schedule-trained S-201 and multiple-schedule-trained S-203.* S-201's leverpressing in tone (filled-circles) and light (open-circles) only produced $\overline{TL}$ (pen-depressed) wherein it received food (hatch-marks) for not responding – making $\overline{TL}$ preferred over tone or light. S-203's, leverpressing earned food in tone and in light SDs, with comparable food in $\overline{TL}$ for not leverpressing. Adapted from Weiss and Van Ost (1974), Figure 1.

Despite these similarities in baseline behavior, the stimulus-compounding tests produced dramatically different results in Groups A, B and C. Figure 2 presented the tripled response rate in T+L of Group A rats trained on multiple VI EXT. All multiple VI DRO-trained rats (Group B) responded at about twice the rate during T+L as during tone or light (Figure 4, left) while no chain VI DRO-trained rat (Group C) responded more during T+L than during tone or light (Figure 4, right). This revealed that: (1) the discriminative-response process alone was sufficient to double the rate of responding in T+L over responding in either tone or light alone, (2) this response enhancement was less than the 3:1 increase T+L produced in Group A (Figure 2) where discriminative- and incentive-motivational processes were operating in concert [both increasing (S-R↑, S-S^r↑)], and (3) T+L did not enhance responding after chain VI DRO-training (Group C) even though tone and light *each* occasioned responding *indistinguishable* from that of Groups A and B. This failure of T+L to increase responding can be attributed to the chain-schedule arrangement producing conflicting discriminative-response and incentive-motivational properties (S-R↑, S-S^r↓) to the tone and the light S^{D}s.

Figure 5 presents the percent of stimulus-compounding test responses to T+L by Groups A, B and C. With baseline behavior *indistinguishable* over groups, the stimulus-compounding assay was necessary to produce this *instrumentally-derived appetitive incentive-motivational function* that reveals the incentive-motivational contribution to underlying stimulus control. On these tests, Group A (S-R↑, S-S^r↑) emitted over 60% of its total responses during T+L, Group B (S-R↑, S-S^r=) about 50% and Group C (S-R↑, S-S^r↓) less than 30%. The vertical lines through each Group's data point in Figure 5 represent the *range* of values averaged to produce the percent of total-test responses emitted in T+L by that group. The complete *absence* of group overlap reveals the extent of group homogeneity and supports the incentive-motivational processes' potency.
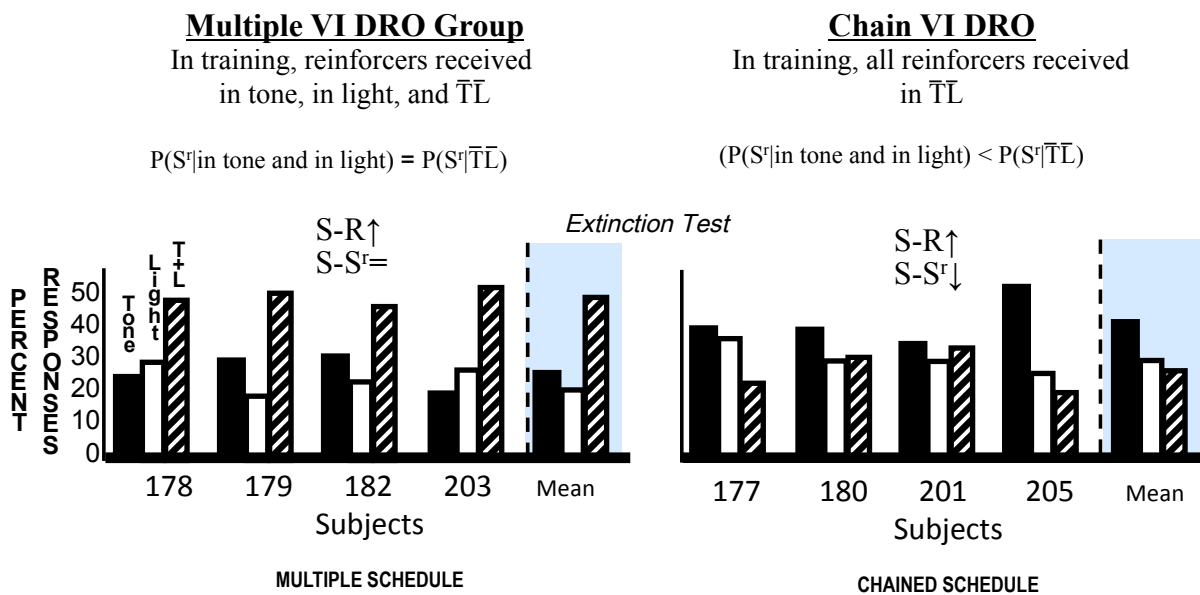
Stimulus-Compounding Test

Figure 4. *Stimulus-compounding tests of behaviorally comparable groups that lever pressed in tone and in light S^{D}s and ceased in $\overline{T}\overline{L}$.* With conflicting (S-R↑, S-Sr↓) properties established to S^{D}s (chain-schedule), tone, light and T+L rates were comparable. With only S-R↑ established to tone and to light (multiple-schedule), T+L doubled responding. Adapted from Weiss and Van Ost (1974), Figure 2.

Although the results for different groups of subjects presented in Figure 5 were obtained from different experiments (Weiss, 1969; Weiss, 1971, Exp. 2; Weiss & Van Ost, 1974), the validity of the comparisons reported therein are supported by the fact that: (1) each group contributing to the function was *replicated* in an experiment containing another group, with original-and-replicated groups indistinguishable (note Figure 5's narrow, non-overlapping range bars), (2) to control for differences in response rates across subjects each was equally weighted in this and subsequent functions by converting its output to tone, light and T+L test stimuli to a percentage of its total-test responses, and (3) all studies were conducted in the same laboratory and used the same operant enclosures, species, S^{D}s, reinforcers, temporal parameters, etc.

Presenting T+L tripled Group A's responding – whose tone and light S^{D}s *each* occasioned lever pressing (S-R↑) and were also associated with food increase (S-S^r↑). But, the part played by the appetitive-incentive-motivational process in this enhancement can only be appreciated in comparison to Group B – whose S^{D}s occasioned lever pressing (S-R↑) without signaling reinforcement change (S-S^r=). In Group B, T+L only doubled response rate (Figure 4, left frame and Figure 5). This 2:1 response enhancement implies a simple

additive summation when *only* the discriminative-response process (S-R↑, S-S^r=) is activated. That result is especially intriguing in the context of the simple additive summation Pavlov reported [cited by Kimble (1961)] in a *pure* classical-conditioning situation. The odor of oil of camphor ordinarily evoked 60 drops of saliva and a mild shock usually produced 30 drops. Compounding these stimuli evoked 90 drops.
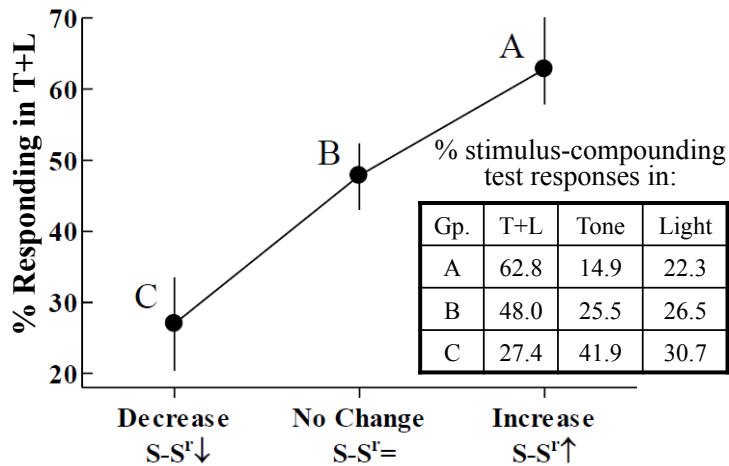

Figure 5. *Instrumentally-derived appetitive incentive-motivational function.* On stimulus-compounding tests, compared to tone or light alone, T+L tripled responding in Group A (S-R↑, S-Sr↑), doubled responding in Group B (S-R↑, S-Sr=) and didn't change responding in Group C (S-R↑, S-Sr↓). Group A from Weiss (1969, 1971 Exp. 2). Groups B and C from Weiss (1971 Exp. 2) and Weiss and Van Ost (1974). See Weiss (2014) Figure 4 caption for additional analysis.

Producing the Instrumentally Derived Incentive-Motivational Function: Aversive

The instrumentally-derived appetitive incentive-motivational function enhances our understanding of intersections and interactions between operant and classical conditioning. This would be deepened by demonstrating generality of these interactions with aversive-instrumental contingencies. Data relevant to the extreme points in Figure 5 are available and will be briefly described next. The tactics employed with shock-avoidance are functionally the same as in the food-related experiments described above.

Emurian and Weiss' (1972) rats postponed shock for 25-s on a free-operant-avoidance (FOA) contingency (Sidman, 1953) by lever pressing during tone and during light S^{D}s, while $\overline{TL}$ was shock-free. Figure 6 (upper record) shows that these rats lever pressed during the S^{D}s and ceased in $\overline{TL}$, indicating that these S^{D}s each possessed a discriminative-response property (S-R↑) comparable to that in the food schedules described earlier (see Groups A, B and C, in Figure 5). Additionally, by being differentially correlated with shock these S^{D}s increased avoidance incentive (S-S^r↑) or, more colloquially, produced *fear*. As expected, compounding aversive S^{D}s with S-R↑, S-S^r↑ properties produced almost 2.5 times the avoidance responses as the highest-rate-single stimulus. Tone + light controlled 58.6% of total-test responses (Figure 7, Point A).
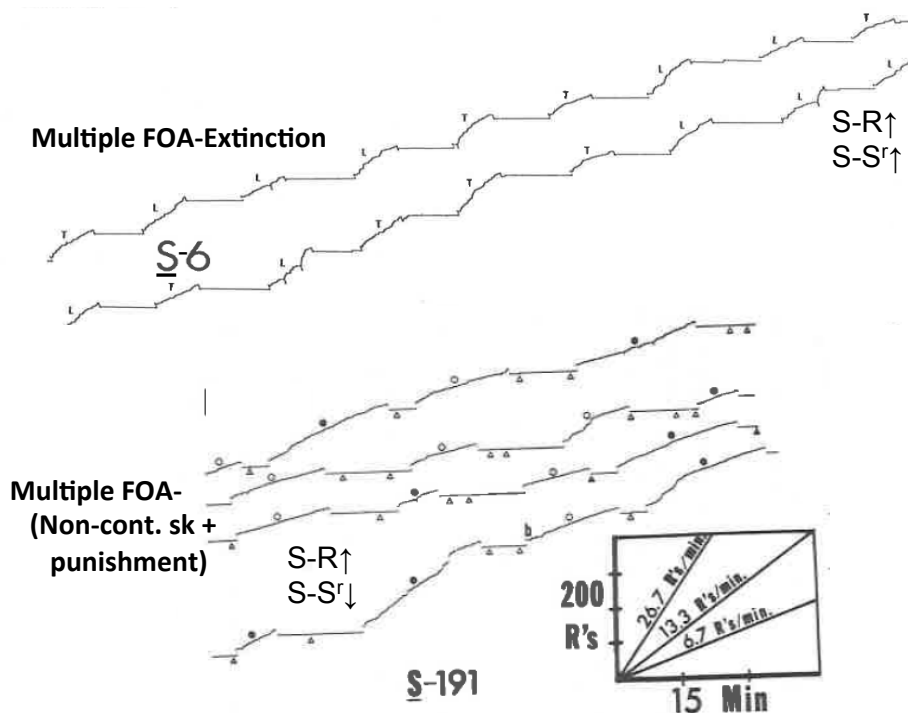
Figure 6. *Cumulative records show these rats are behaviorally comparable, with S-R↑ established to tone and to light S^Ds.* Both lever pressed at moderate, steady rates to postpone shock (hatch-marks) in tone (T-or-filled circles) and light (L-or-open circles) S^Ds. Pressing ceased when S^Ds were absent $\overline{TL}$ (pen depressed). But (see text) these S^Ds increased avoidance incentive (S-S^r↑) in S-6 and decreased it (S-S^r↓) in S-191. S-6 from Emurian and Weiss (1972). S-191 from Weiss (1976, Exp. 3, Phase 1).

     Weiss (1976, Exp. 3, Phase 1) used the same training chambers, stimuli, species etc., as Emurian and Weiss (1972). Additionally, as in Emurian and Weiss' study, rats' lever pressing postponed shock on free-operant avoidance during both tone and light S^Ds. But now shock-related contingencies were programmed in $\overline{TL}$ to make it more aversive than tone or light. In $\overline{TL}$, unsignalled-unavoidable shock was delivered intermittently and lever pressing produced immediate shock (punishment).

     It was explained earlier that with positive reinforcement maintaining behavior the preferred condition possesses the greater excitatory-incentive value because one is working to produce an *attractive* event. Negatively-reinforced behavior would be viewed symmetrically. Therein, the non-preferred condition possesses the greater excitatory-incentive value because one is working to remove a *repelling* event. Why Weiss' training arrangement would have made in $\overline{TL}$ more aversive than tone or light (1976, Exp. 3, Phase 1) is explained below.

     Effective avoidance (Figure 6, S-191) led to shock-rates during tone or light (0.22 shocks/minute) being only half those in $\overline{TL}$ (0.53 shocks/minute). Therefore, on the basis of relative-shock-rate alone presentation of tone or light should reduce (S-S^r↓) aversive incentive-motivation (*fear*) *relative* to that in $\overline{TL}$– even though shocks occurred during all three conditions. In addition, it follows from Badia and Culbertson (1972) that signaled-avoidable shock should be preferred to unsignalled-inescapable shock. That would have further reduced aversive incentive-motivation during tone and during light S^Ds where shock was: (1) *predictable* from time elapsing since S's response (Anger, 1963), and (2) *controllable* since it could be avoided. Contrast that with $\overline{TL}$wherein shock was provided both independent of, and dependent on,

responding. Therefore, shock predictability, controllability and lower rate were all contributing to the tone and the light S^Ds reducing *fear*.

Instrumentally-Derived Aversive Incentive-Motivational Function

Gp.	T+L	Tone	Light
A	58.6	25.9	15.5
B	35.3	31.2	33.5

% stimulus-compounding test responses in:

Avoidance Incentive Established to Tone and to Light S^Ds
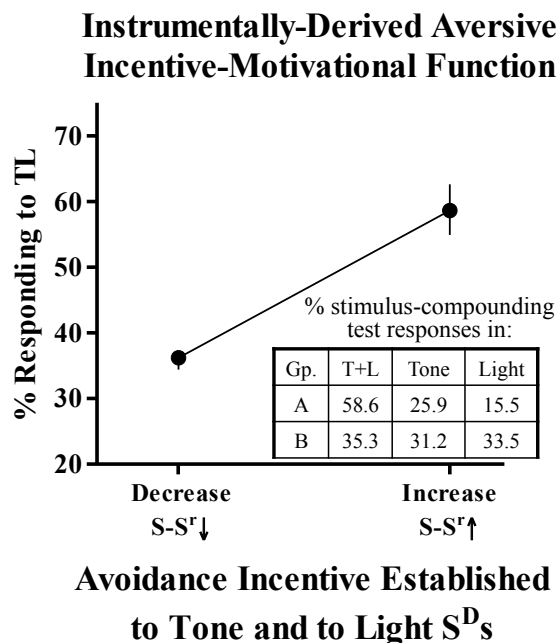
Figure 7. *Instrumentally-derived aversive incentive-motivational function.* On stimulus-compounding tests, compared to tone or light alone, T+L increased responding 2.5 fold in Group A (S-R↑, S-S^r↑) and did not change responding in Group B (S-R↑, S-S^r↓). Range-bars again reveal non-overlapping groups with minimal variability. Group A from Emurian & Weiss (1972). Group B from Weiss (1976, Exp. 3, Phase 1). See Weiss (2014) Figure 6 caption for additional analysis.

The S-R↑, S-S^r↓ combination of S^D properties did not enhance responding with appetitive-related-compounded S^Ds (Group-C, Figure 5). Here again, but in the aversive situation, when discriminative-response and incentive-motivational processes were conflicting response rates during tone, light and T+L were comparable. Tone-plus-light controlled only 35.3% of total-test responses (Point B, Figure 7). Nevertheless, S̲-191's cumulative record (Figure 6, bottom) shows behavioral control comparable to S̲-6 for whom T+L increased avoidance-rate 2.5 fold. The instrumentally-derived-aversive incentive-motivational function (Figure 7) is remarkably similar to Figure 5's based on appetitive control. This supports the generality of the incentive-motivational-process.

Both functions show that resultant behavior is the product of discriminative-response and incentive-motivational processes activated by the compounded S^Ds. Viewing this within a larger historical context it should be recalled that Hull's (1952) *behavior system* included habit (sHr) and incentive motivation (sKr) among the factors combining to produce resulting excitatory potential (sEr). But, by this time, it should be obvious that underlying stimulus control cannot be completely appreciated from baseline-training behavior. The stimulus-compounding assay was necessary to reveal it. That could be why psychologists are often faulted for not *understanding* behavior adequately. Weiss (2014, Table 4) reconciles these dramatically different stimulus-compounding test outcomes by groups that are behaviorally indistinguishable on their training baselines through a composite-stimulus control analysis (e.g., Weiss & Schindler, 1987).

Discussion

Rescorla and Solomon's (1967) treatise supporting two-process learning theory was largely based on the three-stage transfer-of-control (TOC) paradigm that separates, and then *synthesizes*, the two processes Mowrer (1947, 1960) identified within discriminative-operant situations. In Phase 1 of a transfer-of-control experiment, Rescorla and LoLordo's (1965) dogs' hurdle-jumping postponed shock on a continuously operating free-operant avoidance schedule. In Phase 2, inescapable shock followed CS+ but not CS-. In Phase 3, CS+ doubled jumping and CS- dramatically reduced it. These results were attributed to the excitatory-and-inhibitory motivational properties conditioned to the CSs in Phase 2 mediating avoidance rate. Weisman and Litner (1969) systematically replicated this result with rats' wheel-turning postponing shock.

Applying the transfer-of-control paradigm to appetitive situations was challenging and less successful (e.g., see Dickinson & Pierce, 1977; Overmier & Lawry, 1979; Rescorla & Solomon, 1967). The problem is that a food-paired CS+ elicits behaviors that can (perhaps inevitably) compete with the operant response that is used as a dependent variable (DV) — unless the operant-and-elicited responses are similar in topography (LoLordo, McMillian, & Riley, 1974). Overmier and Lawry (1979) described how, after CS+-food pairings, the CS could come to elicit both conditioned orienting and approach towards the food-associated stimulus (*sign-tracking*) as well as orienting and approach to the food trough (*goal-tracking*). In addition, food-signaling stimuli become discriminative for food retrieval. *All* of these behaviors are *incompatible* with the operant DV in appetitive transfer-of-control studies.

Recently, Holmes, Marchand, and Coutureau (2010) comprehensively covered behavioral factors influencing transfer-of-control-related Pavlovian-to-instrumental transfer (PIT). They concluded their systematic "…analyses of data for individual groups in PIT studies suggested that competition between Pavlovian and instrumental responses is an important determinant of PIT [effects]" (p. 1283).

It is worth noting that elicited behavior(s) probably facilitated operant responding in the *successful* transfer-of-control studies supporting two-process theory described above where a shock-related CS+ increased avoidance responding. For example, jumping [Rescorla & LoLordo's (1965) operant] and running [which resembles Weisman and Litner's (1969) wheel-turning operant] are species-specific defense reactions (SSDRs; Bolles, 1970) in the dog and rat, respectively. Therefore, these behaviors elicited (*released*) by their shock-associated CS+ likely facilitated avoidance over what the CS+'s incentive-motivational properties alone would have produced. Such potential facilitation by SSDRs increasing the apparent influence of the CS+ elicited aversive incentive-motivation on avoidance responding deserves investigation. Why this has been essentially ignored for so long, while the competition-of-response problem has received so much attention in the appetitive transfer-of-control paradigm, is puzzling.

The procedures used to obtain the instrumentally-derived incentive-motivational functions presented in Figures 5 and 7 were designed to deal with *competition-of-response* as well as *facilitation of response* problems like those encountered in transfer-of-control experiments. In all instances, target incentive-motivational properties were produced *within* multi-component-operant baselines through food- or shock-related changes during the tone and the light S^Ds, relative to conditions during $\overline{TL}$. But, in all groups these S^Ds always occasioned steady-moderate lever pressing that ceased in $\overline{TL}$ – keeping the influence of the S^D's discriminative-response property comparable over groups. Further, in the appetitive case (Figure 5), the feeder-click, that could produce both elicited and occasioned leverpress-competing behaviors, was not presented during the stimulus-compounding tests performed in extinction.

Nevertheless, it is impossible to prove that something (here, behaviors that could compete with lever pressing) does not occur. They could always be lurking somewhere, yet to be discovered. But, logically, they should not be a factor if a functional analysis showed that such potential, unidentified lever-press-competing

behavior(s) would have led to different stimulus-compounding-test outcomes than those of the groups producing Figure 5 – the instrumentally-derived appetitive incentive-motivational function.

Food-related, lever-press-competing behavior(s) in tone or light are possible in Groups A and B of Figure 5 because in training both obtained food during those stimuli. But such competing behavior should be more likely in Group A, where the S^Ds *differentially* signaled food, than Group B where they did not. Nevertheless, T+L tripled the rate of lever pressing in Group A (relative to tone or light alone) while only doubling it in Group B – results inconsistent with potentially heightened response competition in Group A. Group C's results are even more compelling. Since Group C *never* received food during tone or light, leverpress-competing behavior should have been least likely therein for Group C – where T+L produced response rates that were no higher than during tone or light alone. That lever pressing was an *arbitrary operant* here probably contributed to within-group consistency (see range bars in Figure 5). In nature, rats do not leverpress for food. In the aversive case (Figure 7), shocks were not presented during test components plus lever pressing is not a SSDR.

Conclusion

On multi-component operant baselines, a discriminative stimulus (S^D) generally acquires two kinds of properties. The discriminative-response property results from the different contingencies operating in the diverse environmental conditions the organism encounters. It typically occasions an increase or decrease in response rate with contingency-related *finer grain* control certainly possible. In addition, the S^D becomes differentially associated with reinforcement.[1] Because response-and-reinforcement rates usually co-vary in most laboratory, as well as natural, situations the contribution of each property to resulting stimulus control has often been neglected plus challenging to unravel. The research programs described herein systematically eliminated this co-variation, producing the appetitive and aversive *instrumentally-derived* incentive-motivational functions (Figures 5 and 7) for the first time.

The three-stage operant followed by classical conditioning, transfer-of-control paradigm has traditionally been employed to reveal the influence of classically-conditioned incentive-motive states on operant behavior. Unfortunately, response competition as well as facilitation problems inherent in this design discussed above have challenged interpretation of results produced therein. As explained above, the systematic series of experiments responsible for the instrumentally derived incentive motivational functions presented here were designed to functionally and logically deal with the these problems.

In all five groups responsible for the incentive-motivational functions (Figures 5 and 7) the target incentive-motivational property conditioned to the S^Ds was a product of their being differentially correlated with reinforcement, relative to when they were absent, on the respective multi-component operant baselines. And for that to occur, the operant contingencies had to first influence behavior. It is the author's contention that *in nature* it is this feature of multi-component operant baselines that models the way in which originally neutral environmental conditions usually come to acquire the ability to generate incentive-motive states. There was no direct classical conditioning, in the traditional Pavlovian CS-UCS sense, on any of the operant baselines used to generate the instrumentally derived incentive motivational functions. It could be of historical interest that the author presented these instrumentally-derived incentive motivational functions, and the conclusions he reached from them, for the first time during his Fulbright Lectures at Pavlov Medical University in St. Petersburg, Russia (see Figure 8).

Weiss (2014) presents an integrative account of how instrumentally derived incentive-motivational states are involved in a variety of behavioral phenomena that include stimulus generalization peak shift, selective associations plus the results of stimulus compounding in a wider variety of situations than presented

here. That integration often incorporated Konorski's (1967) appetitive-aversive-interaction theory of motivation. This theory based on *attractive* and *repelling* conditions is parsimonious and *psychological* because it treats the individual as a *hedonic comparator*.
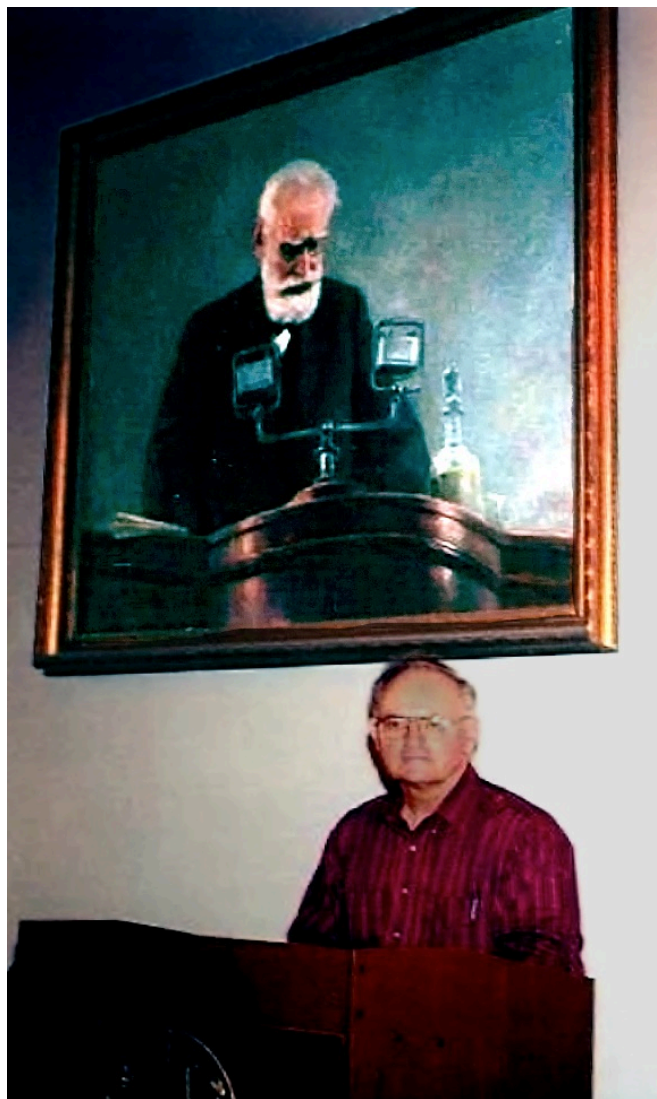

Figure 8. *The author presenting a Fulbright Lecture in the Great Hall of Pavlov Medical University in St. Petersburg, Russia under a portrait of Ivan Pavlov.* It is there that he first formally presented the instrumentally derived incentive-motivational functions. He went on to propose they supported that in nature most incentive-motive states are probably not produced by traditional Pavlovian CS-UCS pairings. Rather, these states are a product of the reinforcement differences that come to exist during different discriminative stimuli present in the environment as operant stimulus control develops.

The centrality of such incentive-motive processes in determining behavior is additionally affirmed by the consistent, about 3:1, response enhancement when stimuli with S-R↑, S-S^r↑ properties are compounded -- whether the reinforcer is food (Weiss, 1971, Exp. 2), water (Weiss, Schindler, & Eason, 1988), shock-avoidance (Emurian & Weiss, 1972), cocaine (Panlilio, Weiss, & Schindler, 1996) or heroin (Panlilio, Weiss,

& Schindler, 2000)]. The important instrumentally derived central-motivational states operating here clearly deserve further investigation at both the behavioral and neuroscience levels.

Before concluding, another most important reason that we fully appreciate the conditions responsible for creating incentive-motive states deserves attention. There is evidence that the incentive-motive properties of environmental conditions associated with events such as shock and drug-self administration can become even more *energizing* than these events themselves. For example, Sidman and Boren (1957) concluded their data "… indicate that the stimulus-shock pairings actually make the warning stimulus more aversive than the shock from which it derived its function" (p. 343).

Likewise, Tunstall and Kearns (2014) recently reported a difference between the direct reinforcing effects of drug vs. non-drug reinforcers themselves compared to the reinforcing effects of environmental conditions associated with these reinforcers. While their rats preferred food over cocaine, a cue paired with cocaine acted as a stronger conditioned reinforcer than a cue paired with food. This clearly could be relevant to the dynamics at the core of addiction. What should be abundantly clear by now is that instrumentally derived incentive-motivational states are central to our understanding of behavior.

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