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THREE VERSIONS OF THE ADDITIVE THEORIES OF BEHAVIORAL CONTRAST

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The additive theories of behavioral contrast state that contrast will occur only when two types of responses interact during multiple schedules. Three more specific versions of the theories may be defined according to how they distinguish these two types of responses. A strong version physically distinguishes them. A second version distinguishes them according to the theoretical processes which control them. A weak version distinguishes them on the basis of the environmental relations which control them. Only the weak version of the theories is currently testable. The weak theory should be tested by establishing each of the two environmental relations independently and then combining them to assess their effect on behavior. Because this test is not usually performed, many of the results which have been taken to support or contradict the additive theories are actually ambiguous.

Key words: behavioral contrast, additive responses, additive theories, multiple schedules, instrumental responses, pigeons, rats

Several additive theories have been proposed to describe the behavioral contrast that occurs when subjects respond on multiple schedules of reinforcement (Gamzu & Schwartz, 1973; Hearst & Jenkins, 1974; Rachlin, 1973). Behavioral contrast may be defined as an inverse relation between the rate of responding emitted during one constant component of a multiple schedule and the conditions of reinforcement obtained from the other variable component (e.g., Rachlin, 1973). Positive contrast refers to an increase in the rate of responding during the constant component produced by a worsening in the conditions of reinforcement obtained from the variable component. Negative contrast refers to a decrease in the rate of responding during the constant component resulting from improvements in the conditions of reinforcement in the variable component. According to the additive theories, increases and decreases in the rates of responding and the conditions of reinforcement should be measured relative to a baseline multiple schedule in which both components provide the same conditions of reinforcement (McSweeney & Norman, 1979).

Recently, confusion has surrounded these additive theories of contrast. Some studies appear to reject one or more of the theories (e.g., Bouzas & Baum, 1976; Hamilton & Silberberg, 1978). Other studies appear to support them (e.g., McSweeney, 1980). This paper will try to clarify some of the confusion. It will not review the entire literature that deals with the additive theories of contast. Rather, it will argue that the basic description of the additive theories can be interpreted in at least three ways, only one of which is presently testable. Then, it will review some of the evidence bearing on this version of the theory. The review of evidence will illustrate that the additive theories, rather than being supported or rejected, have not been properly tested.

THREE VERSIONS OF THE ADDITIVE THEORIES

The additive theories proposed by Gamzu and Schwartz (1973), Hearst and Jenkins (1974), and Rachlin (1973) differ slightly in detail, but all basically state that contrast occurs only when at least two processes or variables interact. One variable, the response-reinforcer relation, controls a type of responding that will be called instrumental responding. The other variable, the stimulus-reinforcer relation, controls a type of responding that will be called additive responding. According to all three theories, positive contrast occurs

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when responses controlled by the stimulus-reinforcer relation facilitate or add to the responses controlled by the response-reinforcer relation. According to Rachlin, and to Hearst and Jenkins, negative contrast occurs when responses controlled by the stimulus-reinforcer relation interfere with or subtract from responses controlled by the response-reinforcer relation. Finally, contrast does not occur if one of the relations is absent or if they both occur but do not interact.[1]

Problems have arisen because this basic theory can be interpreted in at least three different ways depending on how instrumental and additive responses are distinguished. Any one or more of these versions might eventually prove to be correct, but only one of them is currently testable.

A strong version of the additive theories states that additive and instrumental responses can be distinguished on the basis of their physical form. Positive contrast occurs when additive responses take a form that facilitates instrumental responding. Negative contrast occurs when additive responses take a form that interferes with instrumental responding. No contrast occurs when additive responses are absent or when they take a form that does not interact with instrumental responding.

A second, or intermediate, version of the theories distinguishes between additive and instrumental responses on the basis of the theoretical processes that control them. Authors differ in how they characterize these processes; but, as an example, instrumental responses might be attributed to operant conditioning, which occurs because a response is followed by a reinforcer, and additive responses might be attributed to classical conditioning, which occurs because a stimulus signals the reinforcer, now acting as an unconditioned stimulus. In that case, positive contrast would occur only when classically conditioned responses add to or facilitate operantly conditioned responses; negative contrast, only when classically conditioned responses interfere with or subtract from operantly conditioned responses (cf. Rescorla, 1969 a, b). No contrast would occur when only one theoretical process occurs or when both are present but do not interact. According to this theory, operantly and classically conditioned responses might or might not be physically distinguishable.

A weak version of the additive theories distinguishes between the responses on the basis of the environmental relations that control them. Instrumental responses are controlled by a response-reinforcer relation. Additive responses are controlled by a stimulus-reinforcer relation. Positive contrast occurs when both environmental relations are present and their effects on behavior sum.[2] Negative contrast occurs when both are present and their effects at least partially cancel (cf. Rescorla, 1969 a,b). No contrast occurs if only one relation is present or if both are present but do not interact.

The critical environmental relations which control additive and instrumental responses have not been exactly characterized. But, it is usually assumed that any schedule that requires a response for reinforcement arranges the response-reinforcer relation that controls instrumental responses. Stimuli that signal relative increases in the probability or magnitude of reinforcement, such as the stimuli during autoshaping (e.g., Brown & Jenkins, 1968), omission (e.g., Williams & Williams, 1969), or during the more favorable component of multiple variable time variable time (mult VT VT) schedules (e.g., Gamzu & Schwartz, 1973), arrange the stimulus-reinforcer relation that produces positive contrast. Stimuli that signal a relative decrease in the probability or magnitude of reinforcement, such as the stimuli during the less favorable component of mult VT VT schedules, arrange the stimulus-reinforcer relation that produces negative contrast.[3]

The weak version of the additive theories differs from the strong version because it does not require that the two types of responses differ physically. The weak theory differs from the intermediate theory because it is neutral about how the two environmental relations control behavior. In fact, the weak theory could be correct even if the two types of environmental relations proved to be two different ways of manipulating the same theoretical mechanism. For example, the response-reinforcer relation might control behavior by arranging an implicit stimulus-reinforcer relation. Or the stimulus-reinforcer relation might control behavior by arranging an implicit response-reinforcer relation. Or the stimulus-reinforcer relation might contribute only one or two responses which are then maintained largely by superstitious response-reinforcer relations, etc. Theories of how the response-reinforcer and stimulus-reinforcer relations exert

their control over behavior are important, but the weak version of the additive theories can be tested without having an answer.

TESTING THE THREE VERSIONS OF THE ADDITIVE THEORIES

The three versions of the additive theories have been distinguished here because they must be tested differently. The strong version would be the easiest to test if it were true. It distinguishes additive and instrumental responses by their physical characteristics. Therefore, the theories could be tested by physically identifying each type of response and by asking whether contrast always occurs when both are present and interact.

Unfortunately, the physical characteristics which distinguish additive and instrumental responses have not been identified. Schwartz tried to distinguish them on the basis of their duration. He argued that short duration responses (shorter than approximately 30 msec) are additive because they occur in situations where additive responses would be expected (Schwartz, 1977a; Schwartz, Hamilton, & Silberberg, 1975; Schwartz & Williams, 1972). Long duration responses (longer than approximately 40 msec) are instrumental because they occur in situations where instrumental responses would be expected (Schwartz, 1977a; Schwartz, et al., 1975; Schwartz & Williams, 1972).

However, other authors have questioned Schwartz' theory. They have not found differences in duration in situations where Schwartz might predict them (e.g., Moore, 1973; Woodruff, Conner, Gamzu, & Williams, 1977). They have argued that the data do not support Schwartz' interpretation without too many special assumptions (Ziriax & Silberberg, 1978). Or they have argued that there are other simpler explanations for differences in response duration (Ziriax & Silberberg, 1978). Therefore, the strong version of the additive theories awaits a more accurate identification of the distinguishing characteristics of additive and instrumental responses before an adequate test can be provided.

The intermediate version of the additive theories cannot be tested at present either. It attributes additive and instrumental responses to fundamentally different theoretical mechanisms, usually operant and classical conditioning. But the question of whether operant and classical conditioning are actually theoretically different forms of control over responding cannot be answered at present. Arguments bearing on this issue will not be reviewed here because they have been presented elsewhere (e.g., Hearst & Jenkins, 1974).

The weak version of the additive theories is testable, however. The theory attributes contrast to the presence and interaction of behavior controlled by the stimulus-reinforcer and response-reinforcer relations. Therefore, the theory could be tested by establishing each of these environmental relations independently and by asking if their behavioral effects interact as predicted.

The response-reinforcer relation could be established by conducting a simple schedule that employed the same instrumental response, stimulus, and reinforcer that were used to show contrast in a multiple schedule. Such a schedule would arrange the response-reinforcer relation because a response would be required for reinforcement, but it would not explicitly arrange a stimulus-reinforcer relation because no stimuli would be supplied to differentially signal reinforcers.[4]

The stimulus-reinforcer relation responsible for positive contrast could be arranged by presenting stimuli during autoshaping, omission, or during the more favorable component of a mult VT VT schedule which used the same stimuli and reinforcers that were used to show contrast. These response-independent procedures arrange the stimulus-reinforcer relation that produces positive contrast because the stimuli signal increases in the probability or magnitude of reinforcement. The procedures do not explicitly arrange a response-reinforcer relation because no response is required for delivery of a reinforcer.

The stimulus-reinforcer relation responsible for negative contrast could be arranged by presenting stimuli during the intertrial interval of an autoshaping procedure, or by presenting the stimulus signaling the less favorable component of a mult VT VT schedule which used the same stimuli and reinforcers that were used to show contrast. These procedures arrange the stimulus-reinforcer relation that produces negative contrast because the stimuli signal decreases in the probability or magnitude of reinforcement. Again, they do not explicitly arrange a response-reinforcer relation

because no response is required for delivery of a reinforcer.

Once the response-reinforcer and stimulus-reinforcer relations have been independently established, testing the weak additive theory requires assessing whether the relations control behavior in ways which interact in the predicted manner when the two relations are combined. One way to answer this question would be to observe behavior in the presence of each relation presented alone. The classes of behavior established by each relation might take forms that would be expected to interact in the way predicted by the theory when the two relations were combined. For example, key pecking might be established as an instrumental response, and then subjects might be observed to withdraw from the stimulus during the stimulus signaling the less favorable component of a mult VT VT schedule (cf. Hearst & Jenkins, 1974). The additive theories would be correct if the stimulus was located on the response manipulandum when negative contrast was observed. The behavior controlled by the stimulus-reinforcer relation would have been shown to take a form that should interfere with the response controlled by the response-reinforcer relation, as predicted by the theories.

But, the additive theories would not necessarily be incorrect if these classes of behavior were not observed. Rachlin (1973) has argued that the interaction between additive and instrumental responses may take place centrally as well as at the periphery. In that case, the stimulus-reinforcer and response-reinforcer relations might each control behavior in ways that interact when they are presented together even though this would not be immediately apparent when observing behavior established by either relation presented alone. Testing for this type of interaction would require a summation procedure that established the two relations independently and then tested the effects of their combination. For example, a summation test for positive contrast might first establish an instrumental response by placing the subjects on a simple schedule of reinforcement. Then, it might arrange the stimulus-reinforcer relation required for positive contrast by placing the subjects on an autoshaping procedure. If the weak additive theories are correct, then responding should be greater during the simple schedule when the stimulus from the autoshaping procedure is also present than when it is not.

A summation test for negative contrast would also establish an instrumental baseline. Then, it might arrange the stimulus-reinforcer relation required for negative contrast by using a stimulus as the signal for the less favorable component of a mult VT VT schedule. If the weak additive theory is correct, then responding should be lower during the simple schedule when the less favorable stimulus is also present than when it is not. These relations between response rates should be true regardless of what behavior is observed when the response-reinforcer or stimulus-reinforcer relations are presented alone.

Summation tests are not unique to testing the additive theories; they have been described elsewhere (e.g., Rescorla, 1969 a, b). Therefore, they will not be described in detail here. However, it should be noted that control groups or conditions must be included to insure that the change in responding actually results from the simultaneous presentation of the two relations, and not from nonspecific factors. For example, Rescorla (1969 a, b) has discussed ways to separate decreases in response rates produced by the presence of the stimulus-reinforcer relation from decreases in responding produced by fluctuations of attention or by decreases in generalization with the introduction of a new stimulus. Similar controls must also be included as appropriate when testing the additive theories.

Figure 1 may clarify the test of the weak additive theories by illustrating hypothetical results which would conform to the theory. The upper set of graphs tests the theory of positive contrast; the lower graphs test the theory of negative contrast. In each graph, the x-axis represents time and the y-axis, the rate of emitting the response that shows contrast or one that would facilitate it. The vertical lines represent transitions between experimental conditions. The first and third panel of each graph represents a baseline. The middle panel represents the experimental manipulation. Baselines have been recovered before and after each experimental manipulation to insure that the change in responding was produced by the experimental manipulation, not by fluctuations in responding over time. The rates of responding drawn on Figure 1 should be interpreted as presenting ordinal informa-

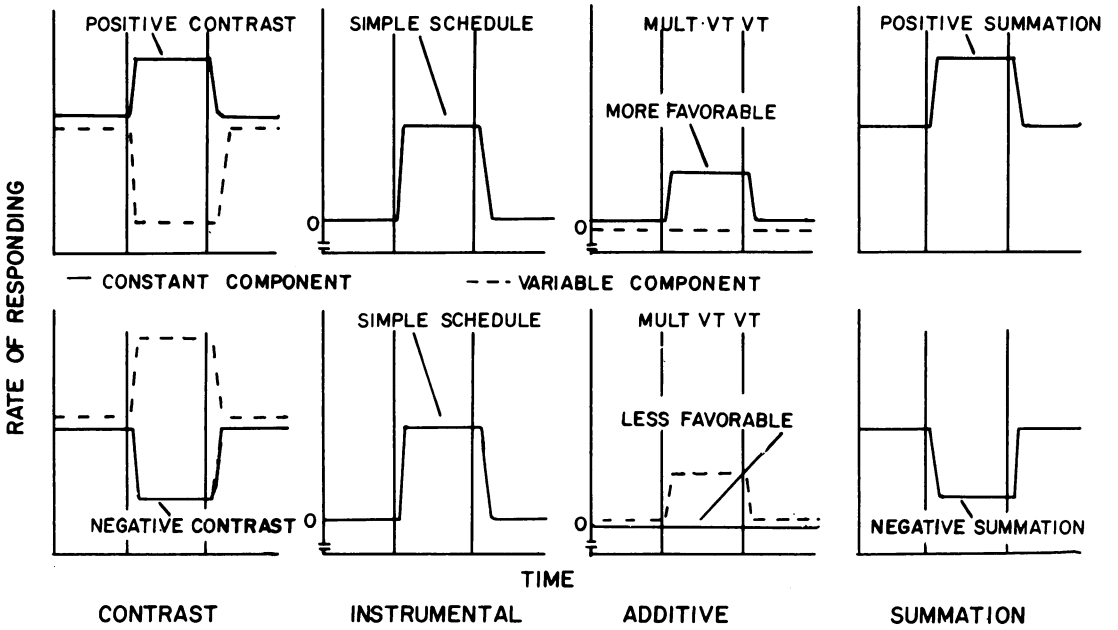

Fig. 1. Hypothetical results of an experiment supporting the weak additive theory. All graphs present the rate of responding on the y-axis and the time on the x-axis. The vertical lines drawn on each graph separate a baseline from the experimental manipulation and then from a recovery of baseline. The upper set of graphs represent tests of positive contrast; the lower, tests of negative contrast. The first graphs from the left demonstrate contrast as the additive theories would define it. The second graphs independently establish a response-reinforcer relation. The third graphs independently establish a stimulus-reinforcer relation. The fourth graphs show that the two environmental relations interact in their control over behavior in the manner predicted by the additive theories.

tion only. That is, Figure 1 presents increases and decreases in response rates as they should occur if the theory is correct, but the sizes of these increases and decreases are not known.

The two graphs farthest to the left illustrate positive and negative contrast as the additive theories would define them (cf. McSweeney & Norman, 1979). The first and third parts of these graphs are baseline multiple schedules which present the same rates of reinforcement in the two components (e.g., mult VI x VI x schedules). The middle part of the graph represents responding during a multiple schedule in which one constant component provides the rate of reinforcement provided during the baseline (e.g., VI x) schedule and the other variable component provides a lower (positive contrast) or higher (negative contrast) rate of reinforcement. The increase or decrease in the rate of responding emitted for the constant reinforcer (i.e., the VI x component) during the middle section or the graph represents positive or negative contrast.

The next three sets of graphs present the results of experimental procedures which test the additive theories' explanation for contrast. The second sets of graphs from the left establish the response-reinforcer relation required for contrast. The response that showed contrast is reinforced on a simple schedule which uses the same reinforcer that was used when contrast was observed. The baseline conditions might present the same rate of reinforcement given by the simple schedule, but reinforcers are given independently of behavior.

The third set of graphs establishes the stimulus-reinforcer relation responsible for positive or negative contrast using the same stimuli and reinforcers that were used when contrast was observed. The baselines present the same stimuli and reinforcers given during the experimental manipulation except that the stimuli and reinforcers occur randomly with respect to each other.

The final set of graphs tests the weak additive theory by examining the interaction of instrumental and additive responses during the summation test. The instrumental response is

established by reinforcing the response on a simple schedule. The proper stimulus-reinforcer relation is established by placing the subjects on appropriate response-independent procedures. Finally, the stimulus is superimposed on the schedule, presenting the two relations at the same time. If the additive theories are correct, then responding should increase during this manipulation when the stimulus-reinforcer relation is the one that produces positive contrast. It should decrease when the stimulus-reinforcer relation is the one that produces negative contrast.

Several points should be noted about Figure 1. First, the test of the additive theories, which is presented in the second, third, and fourth parts of the Figure, should be conducted with a different set of subjects than those which responded during the contrast test. Parts 2 and 3 should be conducted in a different order for different subjects. This will prevent the subjects' past history from biasing the results. Second, the additive theories might be correct regardless of the patterns of behavior observed in the second and third graphs. The theories are not actually tested until the summation tests in the fourth panel. Summation might take place in Part 4 even if it would not be expected by observing the overt behavior during each relation presented alone. Third, a random control group could substitute for the baseline conditions in the second and third graphs. The baseline conditions show only that the environmental relations, and not nonassociative factors, produced the change in behavior. Conducting random control groups may do this more efficiently because they do not destroy the effect of the environmental relations before the summation test is conducted. Conducting a second baseline destroys the environmental relations which must then be reestablished before the summation test can be conducted.

The second and third sets of graphs have been drawn here as they would occur if the experimenter were interested in observing behavior during each of the environmental relations presented alone, and if the additive responses took a form which physically interacted with the instrumental response. That is, responses that would facilitate the instrumental response have been shown to occur during the stimulus-reinforcer relation that produces positive contrast. No facilitating responses have been drawn during the stimulus-reinforcer relation for negative contrast. Interfering responses would presumably be observed during this relation, if other responses had been plotted. However, again, a failure to find the pattern of results depicted in the second and third graphs would not necessarily reject the weak additive theory. Only the results presented in the fourth graph provide a crucial test.

Figure 1 illustrates that the weak version of the additive theories is testable. The results could easily fail to fit these patterns.

THE WEAK ADDITIVE THEORY HAS NOT BEEN TESTED

In an extensive review of the literature, no study was found which adequately tested the weak version of the additive theories. Generally, studies show (or do not show) contrast, and then their authors assume that additive and instrumental responses could or could not have interacted in such a way to produce these results. In many cases, the assumption that the response is an instrumental response could be justified by past experiments which did study the response during simple schedules. For example, few people would doubt that pigeons would peck keys for food reinforcers delivered by simple schedules (cf. Catania & Reynolds, 1968). However, assumptions about whether the response is an additive response, and about how additive and instrumental responses would interact, are typically unjustified.

Tables 1 and 2 summarize some of the studies that have been taken as supporting or opposing the additive theories in the past. The predictions tested by the studies and the problems with interpreting their results have been briefly described. Predictions and problems have been described only briefly because conclusive studies were not found. Readers are referred to the original papers for more detailed descriptions.

Three points should be noted about these tables before examining them. First, the tables are not a complete review of the literature about the additive theories. They include only studies that have been assumed to support or contradict the additive theories but that fail to do so because evidence about instrumental and additive responses and their interaction is missing. Evidence bearing on the theories that

is inadequate for reasons other than the specific procedural point being made, has been excluded from the Tables. For example, support for the additive theories has been said to come from studies which show that the sum of instrumental and signal-key responses during a signal-key multiple schedule are approximately equal to the size of contrast during a one-key procedure when food is the reinforcer (Keller, 1974; Schwartz, 1975; Spealman, 1976; Woodruff, 1979). But the results of these studies are hard to interpret for a number of reasons: they tested the prediction only indirectly (Spealman, 1976); they failed to recover baseline (Keller, 1974; Schwartz, 1975); they failed to find convincing evidence for contrast during a comparable one-key procedure (Keller, 1974); they failed to study responding during signal-key and one-key procedures that provided exactly the same rates of reinforcement (Schwartz, 1975); and they tested the prediction only by comparing across groups (Woodruff, 1979). These data have not been reviewed in this paper because they do not bear on the specific procedural point at issue.

Second, the evidence on many of the assertions in Tables 1 and 2 is conflicting. Particular assertions have been classified as supporting or contradicting the theories according to the weight of evidence. However, the studies which support a different conclusion and the reasons for rejecting them are described in the fourth columns of the Tables labeled "conflicting data."

Third, it should not be assumed that the studies reported in the first columns of the Tables have no procedural flaws. But, it may be assumed that the weight of evidence supports these conclusions and that at least some of the studies reported in the Table to support any one assertion are well-designed.

Only one of these studies came close to testing the weak additive theory. Bradshaw, Szabadi, and Bevan (1978) failed to find responding during a response-independent procedure similar to a multiple schedule that produced contrast when rats pressed bars. Therefore, they provided evidence bearing on the first and third set of graphs in Figure 1 for positive contrast. Bar pressing might also be assumed to have been an instrumental response for their rats if it had been tested, providing evidence for the second set of graphs. But, Bradshaw et al. did not conduct the crucial summation test, represented by the fourth graph of Figure 1. They would have provided good evidence against the additive theories if they had actually shown that additive and instrumental responses did not interact as predicted by the theory. Instead, they only assumed that this interaction would not take place because it was not apparent in the subjects' behavior when the two relations were presented separately. A study should replicate their procedure and carry out the summation test, in order to address the weak form of the theory.

CLARIFICATION AND CONCLUSIONS

Before closing, the present argument may be clarified by noting several points. First, this paper does not argue that any one or all of the additive theories are correct. There are undoubtedly problems with specific predictions of each of the theories. For example, Rachlin's prediction that contrast depends only on the relation between the prior and present component has been contradicted by studies showing that the following component may also play a role (Williams, 1976, 1979). Rachlin's prediction that overall contrast cannot occur without local contrast is also contradicted by studies reporting them independently (e.g., Buck, Rothstein, & Williams, 1975; Malone, 1976). Even the basic theory may not necessarily be correct. The one testable version has not been adequately tested, and the one study that comes closest to testing it, contradicts it (Bradshaw, et al., 1978). Much more evidence is needed to decide whether the theory is correct.

Second, this paper does not argue that testing the additive theories will be easy. The weak additive theory is not well-enough defined to avoid problems in testing it. Problems may come from several areas. For example, the additive theories have not provided a good definition of the "stimulus-reinforcer" and "response-reinforcer" relations. The theories have agreed that some standard procedures arrange these relations, but the theories have differed in their characterization of the relation that these procedures arrange. Additive responses have been said to occur whenever there is a transition between stimuli that differ in value (Rachlin, 1973), whenever stimuli differentially predict reinforcers (Hearst & Jenkins, 1974), or whenever a stimulus-reinforcer

Table 1

Studies which may Support the Weak Additive Theory

Study	*Findings and Interpretation*
Bottjer, Scobie, & Wallace (1977) Redford & Perkins (1974) Schwartz (1974) Schwartz (1975)	The authors failed to find positive contrast when diffuse stimuli signaled the component of multiple schedules. Instrumental and additive responses may not interact in these situations because diffiuse stimuli may not direct additive responses to the instrumental operandum.
Hemmes (1973) McSweeney (1978) Westbrook (1973)	Positive contrast did not occur when pigeons pressed treadles for food reinforcers presumably because additive responses do not interact with instrumental treadle presses.
Halliday & Boakes (1974) Hearst & Gormley (1976) McSweeney (1980) McSweeney & Dericco (1976) Spealman & Gollub (1974)	The relation between the rates of responding during simple and multiple schedules depended on the relation between the rates of reinforcement supplied by the components of the multiple schedule, as predicted by the additive theories (cf. McSweeney, 1980).

dependency exists (Gamzu & Schwartz, 1973). As a result, problems will inevitably arise in extending these terms to new procedures. But these sorts of problems arise in testing any theory. The only question is whether the additive theories can eventually define these terms in a reasonable way that is consistent with the data. If they cannot, then they should be rejected.

Third, this paper is not arguing that the additive theories are the only theories which can account for the results which may eventually support them. Some of the data which may eventually support the additive theories may be explained by other theories. Other data may be procedural artifacts. For example, Davison and Ferguson (1978) have argued that the failure to find contrast when pigeons press treadles results from the difficulty of detecting changes in the generally low rates of responding on treadles. But this is not a problem which is peculiar to the additive theories. Any data are compatible with several theories. The real question is whether the additive theories will provide a more useful summary of the data in the future.

Fourth, this paper is not arguing that contrast, or even multiple schedule contrast, is a unitary phenomenon which will eventually be explained by a single theory. Evidence is accumulating to suggest that there is more than one type of contrast. For example, local contrast, a change in the rate of responding with time in a component, has sometimes been distinguished from overall contrast, a change in the rate of responding with changes in the experimental conditions (e.g., Innis, 1978). The evidence suggests that these two types of contrast may not be controlled by the same variables (e.g., Malone, 1976). Therefore, the present paper which describes a theory of overall contrast may not even apply to local contrast. As more and more is learned about behavioral contrast, the breadth of results that any one theory can account for may become more restricted.

Fifth, this paper is not arguing that the weak additive theory is comprehensive enough to provide a satisfying theory of contrast in the long run. All that the theory offers at present is a description that changes in responding during several different procedures should be related; that one type of change in behavior will not be found unless another type of change also occurs. These sorts of correlations between types of behavior in different situations may be the starting point of a theory, but a satisfying theory must eventually provide much more. For example, it should provide a more exact specification of the situations in which additive and instrumental responses will occur and interact.

Table 1 *continued*

Problem(s)	*Conflicting data*
The authors did not conduct independent tests for additive responses and for their summation with instrumental responses. Schwartz (1973) has argued that additive and instrumental responses may interact even when stimuli are diffuse.	Hearst and Gormley (1976) and Westbrook (1973) contradicted these studies by reporting contrast when diffuse stimuli were used. But, the studies failed to recover baseline rates of responding after the contrast phase of the experiment. Therefore, their results cannot be distinguished from fluctuations in responding over time.
No independent tests for additive responses or their interaction with instrumental responses were conducted.	Bushnell and Weiss (1980) reported positive contrast when treadle presses produced food or avoided shock. But, as the authors admit, contrast was small, transient, and absent for some subjects. Baseline rates of responding were not recovered after the contrast phase of the experiment.
The authors did not conduct independent tests for additive responses and their interaction with instrumental responses. When McSweeney (1980) tried to prevent the interaction of instrumental and additive responses, the results did not change, contradicting the additive theories' explanation for these results. Also, the weak additive theory of negative contrast was not tested adequately.	Studies by Bloomfield (1967), Carr and Reynolds (cited in Staddon, 1974), de Villiers (1972), Freeman (1971), Jaffe (1973), Pear and Wilkie (1971) and Terrace (cited in Herrnstein, 1970) contradicted the predictions of the weak additive theories. The problems with these studies are described in McSweeney (1980).

Finally, though, this paper is arguing that the weak version of the additive theory is testable. It is hoped that eventually the theory will be tested properly. If it is confirmed, it may be compatible with a large amount of evidence that the stimulus-reinforcer and response-reinforcer relations interact in other situations (e.g., Gutman & Maier, 1978; Weiss, 1976). This evidence plus evidence about contrast might eventually yield a powerful theory of responding.

REFERENCE NOTES

1. Schwartz (1975) argued against an additive theory of negative contrast. Instead, he argued that Rachlin's theory of negative contrast is logically incorrect. He noted that no additive responses are present when the components of the multiple schedule supply equal rates of reinforcement. Therefore, no additive responses can be subtracted to create negative contrast when the schedules change. Schwartz seems to have misinterpreted Rachlin's theory, however. Rachlin attributed negative contrast to the reduction of instrumental responses by inhibited additive responses, not to the reduction of response rate by the disappearance of additive responses (Rachlin, 1973, p. 221). The idea that inhibited additive responses might decrease response rate by decreasing instrumental responding is compatible with the definition of inhibition given by other authors (e.g., Rescorla, 1969 a, b). Although Rachlin's theory of negative contrast is logically defensible, Schwartz' challenge did raise the interesting possibility that the additive theories might account for positive but not negative contrast.
2. The term "sum" will be used throughout this paper to indicate that the two environmental relations facilitate each other. This facilitation might also take the algebraic form of a sum, but it need not.
3. Reinforcers could also be given according to multiple fixed time fixed time or multiple fixed time variable time schedules. Unless otherwise indicated, predictions which are made for mult VT VT schedules will also apply to these schedules, and predictions made for mult VI VI schedules will apply to any response-dependent multiple schedule.
4. Some theorists would argue that responses which occur during multiple schedules must also occur during simple schedules because responding on the two schedules is governed by the same theoretical mechanism (e.g., Herrnstein, 1970). But others have argued that this need not be true (e.g., McDowell, 1980). Simple schedules should be conducted to clearly establish a response as an instrumental response until this dispute is settled. Simple and multiple schedules clearly differ procedurally and therefore may control responding in different ways.
5. Williams and Heyneman (1981) have also argued that their results would not unequivocably support the additive theories even if contrast clearly failed to occur on the instrumental key. They argue that the failure to find contrast can be attributed to changes in the response units from the nondifferential to the differential multiple schedule, rather than to the failure of additive and instrumental responses to interact. According to Williams and Heyneman, animals can safely ignore the stimulus on the signal key when both stimuli signal the same rates of reinforcement. But subjects cannot ignore this stimulus when the stimuli signal different rates of reinforcement. As a result, the form of the response may change from a peck during the nondifferential phase to a look-plus-peck during the differential phase. The change in re-

Table 2

Studies which may Oppose the Weak Additive Theory

Study	*Findings and Interpretations*
Allison (1976) Beninger (1972) Beninger & Kendall (1975) Bradshaw, Szabadi, & Bevan (1978) Gutman (1977) Gutman & Sutterer (1977) Gutman, Sutterer, & Brush (1975) Henke, Allen, & Davison (1972) Jensen & Fallon (1973) Mackintosh, Little, & Lord (1972) Uhl & Homer (1974) Wilkie (1972)	Contrast was reported when rats pressed bars for such reinforcers as food and brain stimulation. Additive theorists (e.g., Rachlin, 1973) have argued that additive responses do not interact with instrumental responses when rats press bars.
Schwartz (1978) Woodruff (1979)	Contrast appeared on the instrumental key during a signal-key procedure even though additive responses should have moved from the instrumental to the signal key (cf. Catania, 1973).
Bouzas & Baum (1976)	Positive contrast was reported when time-spending was the instrumental response. The authors argued that time-spending could not be an additive response that would interact appropriately with instrumental responses to produce contrast.
Hamilton & Silberberg (1978)	Positive contrast occurred even though the appropriate additive responses were not reported during a comparable response-independent procedure.
McSweeney (1978)	Negative contrast was found when pigeons press treadles even though the absence of positive contrast for treadle-pressing may imply that additive responses do not interact appropriately with the instrumental treadle presses.
Davison & Ferguson (1978)	Positive contrast was found when pigeons press treadles even though the additive theories argue that additive responses do not interact with the instrumental treadle-press.

sponse form would reduce response rate and mask any positive contrast that did occur.

This argument does not necessarily contradict the weak version of the additive theories, however. The theories are silent about how the response-reinforcer and stimulus-reinforcer relations interact. Therefore, the stimulus-reinforcer relation might alter instrumental responding by changing the physical form of the response without rejecting the theory.

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Table 2 *continued*

Problem(s)	*Conflicting data*
No independent tests for additive responses or their summation with the instrumental bar press were conducted. Other studies have reported bar-pressing during procedures which arrange a stimulus-reinforcer relation, suggesting that the bar press may be an additive response (Atnip, 1977; Locurto, Duncan, Terrace, & Gibbon, 1980; Locurto, Terrace, & Gibbon, 1976; Peterson, 1975; Peterson, Ackil, Frommer, & Hearst, 1972; Smith, Borgen, Davis, & Pace, 1971; Stiers & Silberberg, 1974). However, these studies have not used procedures which are similar to those reporting contrast, and no summation tests have been conducted.	Pear and Wilkie (1971), Porter and Allen (1977) and Premack (1969) failed to find contrast when rats pressed bars, but none of these studies recovered baseline rates of responding after the contrast phase of the experiment. Therefore, their results cannot be distinguished from fluctuations in responding over time.
The authors did not conduct independent tests for additive responses on the instrumental key or for the summation of instrumental and additive responses. An independent test for additive responses would duplicate all aspects of the procedures except it would remove the response-reinforcer relation. The summation test would superimpose these stimuli on an independently established instrumental baseline.	Keller (1974), Schwartz (1975), Schwartz, Hamilton, and Silberberg (1975), and White and Braunstein (1979) supported the additive theories by failing to find contrast on the instrumental response key during a signal-key procedure. But Schwartz (1975) failed to recover baseline. Therefore his results cannot be distinguished from fluctuations in responding over time. The other studies failed to conclusively show that contrast would have occurred during a comparable one-key procedure. Therefore, their failure to find contrast cannot be unequivocably attributed to the use of the two-key procedure.[5]
Time-spending may have been an additive response which would interact properly with instrumental responding if it had been tested (cf. White, 1978).	
The authors did not conduct the appropriate summation test, and they did not define positive contrast as the additive theories would define it (McSweeney & Norman, 1979).	
The author did not test for additive responses or their summation with instrumental responses. Without this evidence it is possible that additive responses reduce the rate of instrumental treadle-pressing to produce negative contrast even though additive responses do not increase treadle-pressing to produce positive contrast.	
Independent tests for additive responses and their summation with instrumental responses were not conducted. The data may also be consistent with the conclusion that negative but not positive contrast occurred as the additive theories would define these terms (cf. McSweeney & Norman, 1979). In that case the stimulus-reinforcer relation included in the summation test should be that for negative, not positive, contrast.	

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