DEFINING BEHAVIORAL CONTRAST FOR MULTIPLE SCHEDULES

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Two different definitions of behavioral contrast have been used for multiple schedules. One, interschedule, definition identifies contrast as changes in the rates of responding which occur when subjects move from one multiple schedule to another. The other, intraschedule, definition emphasizes changes in the rates of responding which occur relative to a baseline rate of responding. The baseline is the rate of responding emitted during a multiple schedule that supplies equal rates of reinforcement in the two components. The distinction between these two definitions is important for empirical and theoretical reasons. For example, theoretical confusion has arisen when the interschedule definition has been used to test and reject theories which implicitly define contrast by the intraschedule definition.

Key words: behavioral contrast, multiple schedules, interschedule definition, intraschedule definition, rate of reinforcement, rate of responding

Behavioral contrast is an inverse relation between the rate of responding emitted during one, constant, component of a multiple schedule, and the conditions of reinforcement in a second, variable, component. Authors disagree about exactly what changes in the conditions of reinforcement produce contrast; but most agree that changes in the rate of reinforcement are among those that do. For simplicity, this paper will confine itself to contrast produced by changes in the rate of reinforcement.

Behavioral contrast may be termed "positive" or "negative"; however, different researchers define these terms differently, creating confusion in the literature. According to one, interschedule, definition (e.g., Hamilton & Silberberg, 1978), positive contrast is any increase in the rate of responding emitted during the constant component that occurs when the rate of reinforcement obtained from the variable component decreases. Negative contrast is any decrease in the rate of responding that occurs when the variable rate of reinforcement increases.

An example may clarify this. Consider the following set of schedules: multiple variable interval two-minute variable interval two-minute (mult VI 2-min VI 2-min), mult VI 2-

min extinction (ext), mult VI 2-min VI 2-min, mult VI 2-min VI 30-sec, and mult VI 2-min VI 2-min. Positive contrast would occur if the rate of responding emitted during the constant, VI 2-min, component increased when subjects moved from the mult VI 2-min VI 2-min to the mult VI 2-min ext schedule, or from the mult VI 2-min VI 30-sec schedule to the final mult VI 2-min VI 2-min schedule. Both would be positive contrast because responding in the constant component increased when the rate of reinforcement obtained from the variable component decreased (either from VI 2-min to ext or from VI 30-sec to VI 2-min). Negative contrast would occur if the rate of responding emitted during the VI 2-min component decreased when subjects moved from the mult VI 2-min ext to the mult VI 2-min VI 2-min schedule or from the mult VI 2-min VI 2-min to the mult VI 2-min VI 30-sec schedule. Both decreases would be negative contrast because constant-component responding decreased when the variable rate of reinforcement increased (from ext to VI 2-min or from VI 2-min to VI 30-sec).

The second, intraschedule definition (e.g., McSweeney, 1978), assesses positive and negative contrast by comparing the rates of responding emitted during component schedules which supply unequal rates of reinforcement to baseline rates of responding emitted when the components supply equal rates. The equal baseline rates of reinforcement are both iden-

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tical to that supplied by the constant component of the unequal schedule. Positive contrast is any increase in constant component responding over the baseline rate, that occurs when the rate of reinforcement obtained from the variable component decreases to a rate less than that in the constant or baseline component. Negative contrast is a decrease in response rate below baseline that occurs when the variable rate of reinforcement increases to a rate greater than that in the constant or baseline component.¹

In the preceding example, positive contrast would occur if the rate of responding emitted during the VI 2-min component increased when subjects moved from the mult VI 2-min VI 2-min schedule to the mult VI 2-min ext schedule. The increase would be positive contrast because the rate of constant-component responding increased when the variable rate of reinforcement decreased below baseline level (i.e., changed from VI 2-min to ext). A decrease in response rate that occurred when equal components were reinstated (i.e., when subjects moved from the mult VI 2-min ext back to the mult VI 2-min VI 2-min schedule) would be the recovery of baseline; it would not be negative contrast. Negative contrast would occur if the rate of responding emitted during the VI 2-min component decreased when subjects moved from the mult VI 2-min VI 2-min to the mult VI 2-min VI 30-sec schedule. The decrease would be negative contrast because it occurred when the variable rate of reinforcement increased above the rate supplied by the baseline VI 2-min schedule. An increase in response rate that

occurred when equal components were reinstated (i.e., when subjects moved to the final mult VI 2-min VI 2-min schedule) would be another recovery of baseline, not an instance of positive contrast.

Figure 1 illustrates the difference between the two definitions. It presents hypothetical rates of responding emitted during the components of the multiple schedules, as a function of time. The constant component always presents a VI 2-min schedule. The schedules presented during the variable components are indicated by the labels on the abscissa. Transitions between multiple schedules are marked by vertical lines. The rates of responding emitted during the VI 2-min components are indicated by solid lines; the rates emitted during the variable components by dashed lines. Each set of axes represents contrast as it would

Fig. 1. Rates of responding emitted during the components of multiple schedules as a function of time. The solid line represents the rate of responding emitted during a constant, VI 2-min schedule. The dashed line represents the rate of responding emitted during a variable-component schedule. The schedules presented during the variable components are indicated by the labels on the abscissa. The vertical lines represent transitions between multiple schedules. Each set of axes represents contrast as it would be described by one of the two definitions.

¹Technically, either definition might be called "interschedule" because neither can identify contrast without comparing rates of responding and reinforcement across different multiple schedules. However, the first definition has been called "interschedule" because knowledge of the relation between successive schedules is sufficient for identifying contrast by that definition. The second has been called "intraschedule" because information about the relation between schedules must be supplemented by information about the relation between the rates of reinforcement supplied by the components of a single schedule. An increase in constant-component responding cannot be called positive contrast by the intraschedule definition unless the rate of reinforcement obtained from the variable component is less than that obtained from the constant component. A decrease cannot be called negative contrast unless the variable rate of reinforcement is greater than the constant rate.

be described by one of the two definitions. As can be seen from the figure, the intraschedule definition is a more limited view of contrast. Certain effects, treated as contrast by the interschedule definition are viewed as the recovery of baseline by the intraschedule definition.

These two definitions of contrast should be distinguished for several reasons. First, the two definitions do not always lead to the same conclusions. For example, McSweeney (1978) found results that were hard to summarize when the interschedule definition of contrast was applied to the responding emitted by pigeons pressing treadles for food reinforcers. But the results were easily summarized when the intraschedule definition was applied: negative but not positive contrast occurred.

Second, the two definitions should be distinguished because they have important implications for experimental design. Careful attention must be paid to the order in which the schedules are conducted when the interschedule definition is used. Figure 1 shows that the same rate of responding emitted during a component of a mult VI 2-min VI 2-min schedule may represent positive or negative contrast depending on whether it was preceded by a mult VI 2-min VI 30-sec schedule or by a mult VI 2-min ext schedule. Therefore, schedules must be carefully ordered to present the proper transitions between rates of reinforcement. Order of presentation is less important when the intraschedule definition is used. A change in response rate will be identified as positive or negative contrast according to the relation between the rates of reinforcement in the two components relative to a baseline rate, regardless of when the schedule is presented.

Experiments must be designed to determine the baseline rates of responding when the intraschedule definition is used. Positive and negative contrast are defined by response rate changes relative to a baseline. These changes cannot be identified unless the baseline rates of responding, emitted when the two rates of reinforcement are equal, have been accurately assessed. Determining this baseline rate of responding is unimportant when the interschedule definition is used. Changes in the rates of responding from schedule to schedule can be assessed as positive or negative contrast according to the direction of changes in the rates of responding and reinforcement from one schedule to the next, regardless of how

fast the subjects respond when the rates of reinforcement are equal.

Third, the two definitions of contrast should be distinguished because they have different implications for the theoretical question of whether positive and negative contrast are produced by the same factors. Some authors have argued that they are (e.g., Rachlin, 1973); others have argued that they need not be (e.g., Schwartz, 1975). Figure 1 shows that two definitions may produce different answers to this question because they classify positive and negative contrast differently.

Further consideration shows that the two definitions treat the question of the symmetry of positive and negative contrast entirely differently. The question can be answered empirically when the intraschedule definition is used. A set of circumstances might produce positive contrast and fail to produce negative contrast or vice versa (cf. McSweeney, 1978). For example, in Figure 1, the rate of responding emitted during the VI 2-min component might increase when subjects moved from the mult VI 2-min VI 2-min schedule to the mult VI 2-min ext schedule, producing positive contrast. But the rate of responding might not decrease when subjects moved from the mult VI 2-min VI 2-min to the mult VI 2-min VI 30-sec schedule, failing to produce negative contrast.

On the other hand, Rachlin (1973) has argued that positive and negative contrast must be produced by the same factors if the interschedule definition is used, and if the same multiple schedule produces the same rates of responding when it is conducted at two different times. Figure 1 illustrates this point. Suppose that the rate of responding emitted during the VI 2-min component increases when subjects move from the mult VI 2-min VI 2-min schedule to the mult VI 2-min ext schedule, producing positive contrast. Then the rate of responding must decrease when subjects move from the mult VI 2-min ext schedule to the mult VI 2-min VI 2-min schedule, producing negative contrast. Likewise, if the rate of responding emitted during the VI 2-min component decreases when subjects move from the mult VI 2-min VI 2-min schedule to the mult VI 2-min VI 30-sec schedule, producing negative contrast, then the rate of responding must increase when subjects move back to the mult VI 2-min VI 2-min schedule,

producing positive contrast. Figure 1 shows that positive and negative contrast are simply two different ways of looking at the same results if the interschedule definition is used, and if the same rates of responding are emitted when the same schedule is conducted at different times. Therefore, they must be produced by the same factors.

Fourth, the two definitions should be distinguished because one definition has been used to test a theory that implicitly uses the other definition. For example, Hamilton and Silberberg (1978) used the interschedule definition to test the additive theories of contrast (e.g., Hearst & Jenkins, 1974; Rachlin, 1973). But the additive theories implicitly use the intraschedule definition.

The additive theories have argued that multiple schedule behavioral contrast results from the interaction of two types of responses. The first type, instrumental responses, is governed by the relation between the response and the reinforcers it produces. The second type, additive responses, is governed by the relation between the stimuli and the reinforcers that they signal. For example, according to Rachlin's theory, additive responses are excited by transitions from stimuli that signal reinforcers of lower value to those that signal reinforcers of higher value. Additive responses are inhibited by transitions from stimuli that signal higher valued reinforcers to those that signal lower-valued ones. Higher valued reinforcers are those supplied at a higher rate, among other things. Excited additive responses may add to a constant rate of instrumental responding to produce positive behavioral contrast and inhibited additive responses may subtract from instrumental responding to produce negative contrast under some conditions.

This theory and a similar one proposed by Hearst and Jenkins (1974) implicitly use the intraschedule definition of contrast because both theories label changes in response rates in the same manner as the intraschedule definition. They do not conform to the interschedule definition. An example, taken from Figure 1, may illustrate this. Suppose that the rate of responding emitted during the VI 2-min component decreased when subjects moved from the mult VI 2-min ext schedule to the mult VI 2-min VI 2-min schedule. Rachlin's theory would explain this as follows. Both instrumental and additive responses should oc-

cur during the VI 2-min component of the mult VI 2-min ext schedule. Instrumental responses should occur because a response is required to produce a reinforcer. Additive responses should occur because the appearance of the VI 2-min schedule represents a transition from a stimulus signaling a lower rate of reinforcement (ext) to one signaling a higher rate (VI 2-min). When subjects move back to the mult VI 2-min VI 2-min schedule, the instrumental responses should remain because a response is still required for reinforcement. But the additive responses should disappear because the transition to the VI 2-min component no longer represents a transition from a lower to a higher valued stimulus: it represents a transition between stimuli of equal value (i.e., VI 2-min to VI 2-min). Because the decrease in response rates is produced by the disappearance of the additive responses that produce positive contrast, it should be labeled the disappearance of positive contrast, or the recovery of the instrumental baseline, as specified by the intraschedule definition. The decrease should not be labeled the appearance of negative contrast, as specified by the interschedule definition, because it is not produced by the inhibition of additive responses to which Rachlin attributes negative contrast.

Confusion arises when the interschedule definition is used to test the additive theories. For example, Hamilton and Silberberg (1978) placed subjects on a mult VI 33-sec VI 99-sec schedule followed by a mult VI 99-sec VI 99-sec schedule, to determine if contrast occurred. Yoked subjects responded on a mult VT 33-sec VT 99-sec schedule followed by a mult VT 99-sec VT 99-sec schedule. The yoked subjects received free food whenever food was earned by a companion subject responding on the mult VI VI schedules. The mult VT VT schedules were conducted to determine if additive responses occurred under the same conditions that produced behavioral contrast, as the additive theories would predict.

Hamilton and Silberberg questioned the additive theories when they found increases in the rate of responding emitted during the VI 99-sec component when subjects moved from the mult VI 33-sec VI 99-sec schedule to the mult VI 99-sec VI 99-sec schedule but did not find additive responses during the corresponding VT 99-sec component of the mult VT 99-sec VT 99-sec schedule. They argued that the ad-

ditive theories must be incorrect if positive contrast occurs under conditions that do not produce the additive responses to which positive contrast is attributed.

Hamilton and Silberberg implicitly used the interschedule definition of positive contrast. They identified the increase in the rate of responding during the VI 99-sec component as positive contrast because the conditions of reinforcement in the variable component got worse with the change of schedules (i.e., they decreased from VI 33-sec to VI 99-sec schedules). But, as discussed earlier, the additive theories would view this increase in response rate as a return to baseline, not as positive contrast. The additive theories would not expect positive contrast unless the transition to the VI 99-sec schedule represented a transition from a lower to a higher rate of reinforcement. This would be true only if the rate of reinforcement in the variable component had decreased to a rate less than, not equal to, that obtained from the VI 99-sec component. Rachlin's theory would predict that additive responses would be inhibited during the VT 99-sec component of the mult VT 99-sec VT 33-sec schedule, not that they would be excited during the mult VT 99-sec VT 99-sec schedule.

In fairness to Hamilton and Silberberg (1978), their definition of behavioral contrast is consistent with much of the literature. It is even consistent with much of Rachlin (1973), which implicitly used each of the two definitions in different places. For example, as argued earlier, Rachlin used the interschedule definition when he showed that positive and negative contrast must be produced by the same factors. Then, however, he proposed a theory that implied that the intraschedule definition of contrast should be used. The situation became further complicated when he attributed negative contrast to the inhibition of additive responses. He probably used the term "inhibition" as it had been used by previous authors (e.g., Hearst, Besley, & Farthing, 1970; Rescorla, 1969). For example, inhibited additive responses might subtract from other types of responses (e.g., instrumental responses). But the confusion on this issue (e.g., Schwartz, 1975) indicates that this definition was not clear.

In conclusion, the two definitions of contrast should be distinguished to avoid empirical and theoretical confusion. Neither definition is presently preferred. Both definitions should be used to determine whether both types of contrast occur and under what circumstances. The definition which eventually produces the most orderly results and can be reconciled with the major theories of contrast would be preferred. McSweeney (1978) did find the intraschedule definition more useful for describing behavioral contrast when pigeons pressed treadles for food reinforcers. But the interschedule definition might be more useful in comparing multiple schedule contrast to the elation and depression effects reported when rats run in alleyways for food reinforcers (e.g., Crespi, 1944). Elation and depression are defined by comparing the rate of running for a particular reinforcer when it has been preceded by running for a larger or smaller reinforcer. This seems more similar to the interschedule definition.

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