Within-trial Contrast: An Examination of the Conditioning Effects of Differentially Preferred Events on Antecedent and Consequent Stimuli

Dissertation

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Abstract

Stimuli that precede aversive events are typically less preferred than stimuli that precede non-aversive events. Stimuli that follow aversive events, however, may become more preferred than stimuli that follow non-aversive events. This effect has been called within-trial contrast (or alternatively, state-dependent valuation). Research on this effect has primarily been conducted with non-human organisms. In previous research, organisms are presented with an antecedent stimulus which leads into one of two differentially preferred work events. Subsequent to these work events, a consequent event is presented—either another stimulus or a discrimination task. The results of previous research have demonstrated an increase in preference for the stimuli that follow the less preferred work event. However, previous research has rarely documented preferences for the antecedent stimuli, consequent stimuli, or work events prior to training with all stimuli and events. Furthermore, although a change in preference has been documented, it is unclear whether these preference changes also represent a change in reinforcer efficacy. This study attempted to replicate previous research by examining changes in preference for stimuli that occur subsequent to differentially preferred events. In addition, this study extended previous research by (a) measuring preference for work events before training, (b) examining preference changes for antecedent stimuli in addition to consequent stimuli, (c) assessing preference for all stimuli and work events
both before and after training, and (d) assessing whether consequent stimuli were
differentially conditioned as reinforcers. Three young boys with disabilities participated
in this study. The results indicate that for all participants, antecedent stimuli were
conditioned as expected—stimuli were more preferred when they led into more preferred
work events. The within-trial contrast effect, however, was only clearly demonstrated for
one participant. Furthermore, increases in preference for consequent stimuli were not
consistently correlated with increases in reinforcer efficacy. The results are discussed
and explanations provided to account for the different conditioning effects. Limitations
of this study are provided as are directions for future research.
Dedication

To my beautiful wife Rosie whose patience with me throughout this entire process qualifies her for sainthood.

To my mom and dad, my brother John, and Mimi, who have always been so tremendously supportive.
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Chapter 1: Introduction

When an organism is exposed to different schedules of reinforcement, responding to each is generally predictable based on the specific arrangements of the schedule (Catania, 1998). Variable ratio schedules, for example, generally produce rapid and relatively constant responding whereas fixed interval schedules often produce a scalloped pattern with the rate of responding gradually increasing throughout the interval. Different schedules of reinforcement, however, do not operate in isolation and may alternate with one another, occur in combination, or occur in succession. When this takes place and the organism is unable to discriminate a change in schedule, a corresponding change in responding may not immediately occur (Mazur, 2006). For example, when an organism has been responding on a very lean schedule of reinforcement and is shifted to an extinction condition, responding may be slow to completely extinguish. That same organism, however, may very quickly cease responding if shifted from an FR 1 schedule to an extinction condition.

One explanation for this difference in responding during an extinction procedure is based on the organism’s ability to discriminate changes in schedule. From the organism’s perspective, a change from a lean schedule of reinforcement to an extinction condition is difficult to discern. A change from an FR 1 schedule of reinforcement to an extinction condition, on the other hand, is easily discernable. Thus, responding is
extinguished faster when shifting from FR 1 because the organism can discriminate a change in schedule and responds accordingly. If, however, some stimulus is associated with the onset of the extinction condition, the organism may cease responding equally quickly regardless of the previous schedule.

In general, when different schedules of reinforcement are associated with different discriminative stimuli, responding to each schedule may become more stable and predictable (Cooper, Heron, & Heward, 2007), and changes in responding may be more immediate. In addition, when an organism can discriminate changes in current or upcoming schedules of reinforcement it also becomes possible for changes in one schedule to alter responding in another unchanged schedule. This effect has been referred to as contrast.

The idea of contrast, as it has been used in behavioral research, was borrowed from research on visual perception (Zentall, 2005). For example, when presented with an image of a white circle surrounded by black, a contrast between the two images is formed at the edge of the white circle. The effect of this contrast is to make the edge of the white circle appear whiter than the center while simultaneously making the edge of the black shape darker than areas further from the circle. In visual perception, this effect is due to the activation and inhibition of sensory neurons in the retina at the edge where the white and black shapes meet. The general idea of this contrast effect, however, is that the whiteness and blackness of each shape is enhanced by the presence of the other; it is this idea of contrast that has been adopted by behavior analysis.
There is no single definition of contrast in behavioral literature. It has been described as “a comparison between two conditions in which the difference between them is amplified by the presence of the other” (Singer, Berry, & Zentall, 2007, p. 275) or as “an apparent exaggeration of reward differences brought about by animals experiencing two rewards in close temporal proximity” (Flaherty, 1982, p. 410). The basic idea of contrast in behavioral literature is that behavior is not only governed by the immediate schedule of reinforcement, but also by the juxtaposition of two different schedules. The effect is much the same as in visual perception in that, just as the presence of the black accentuates the white, the presence of one schedule of reinforcement magnifies the characteristics of the other schedule and vice versa. The ultimate effect of this magnification is a change in responding. An organism exposed to two juxtaposed schedules responds differently to each than it would had it been exposed to only one of the two schedules. In other words, it is the contrast between the two schedules that influences responding to each schedule.

In order for a contrast effect to occur, the organism must be exposed to two or more different conditions. This exposure is typically done in the context of a multiple schedule of reinforcement (Catania, 1998). In a multiple schedule, two or more different schedules of reinforcement (referred to as components) alternate and each schedule is associated with a different discriminative stimulus (Mazur, 2002). After repeated exposure to a multiple schedule, an organism’s responding to each discriminative stimulus may become dependent not only upon the presence of that discriminative stimulus, but also upon the presence of the other component of the multiple schedule. At
this point, a researcher can alter one component of the multiple schedule and effect an increase or decrease in responding in the other unchanged component. When this change in responding is observed, a contrast effect can be said to have occurred.

A contrast effect may result in an increase or decrease in responding to the unchanged component. An increase in responding, often seen with a corresponding decrease in responding in the other component, is called positive contrast (Schwartz & Gamzu, 1977). The opposite effect, a decrease in responding to the unchanged component, is called negative contrast. For reasons that remain unknown, in laboratory settings, and in particular with incentive and anticipatory contrast (discussed below), it has generally been easier to experimentally demonstrate negative contrast as opposed to positive contrast (Flaherty, 1996).

Several forms of contrast have been investigated in behavioral literature—anticipatory, incentive, and behavioral contrast. These common forms of contrast will briefly be described below as will a more recently identified form of contrast—within-trial contrast.

**Different Types of Contrast**

Various forms of contrast have been investigated in the behavioral literature. Each form of contrast essentially requires a change in responding to one component due to the presence of another component. The various forms of contrast primarily differ from one another based on when in the schedule the organism responds, and which stimulus controls the responding. There is, however, some overlap among the various forms of contrast, particularly in regards to behavioral contrast. The following sections
will briefly describe several prominent forms of contrast that have been investigated and
differentiate one from another. Basic laboratory observations will be described and an
applied example of each contrast effect will be provided.

**Incentive contrast.** Incentive contrast (alternatively known as successive
contrast; see Flaherty, 1996) occurs when a change in reinforcer magnitude results in a
change in responding either above or below what would be expected had no reinforcer
magnitude change occurred. In studies on incentive contrast, an organism is exposed to
two conditions—one condition utilizes large magnitude reinforcers and the other
condition utilizes small magnitude reinforcers. When the organism experiences a shift in
components from large to small magnitude reinforcers, the organism may respond less to
the small magnitude reinforcers than would be expected had the organism not previously
experienced the large magnitude reinforcer. The opposite effect is seen when shifting
from small to large magnitude reinforcers. In these scenarios, the organism responds
more to the large magnitude reinforcer based on prior exposure to small magnitude
reinforcers.

Examples of incentive contrast can be seen in daily life. In a classroom, for
example, a student may engage in a great deal of work if work completion is reinforced
by delivering 10 tokens. If, however, the amount of tokens is suddenly shifted to two
tokens, the student may respond by displaying less work completion than other students
already receiving only two tokens. This is an example of negative incentive contrast
because (a) the student responds less to the two token schedule than would be expected
otherwise, and (b) this diminished responding is due to previous exposure to a denser
schedule of reinforcement followed by a shift to a leaner schedule. Research on incentive contrast has demonstrated that positive or negative contrast effects are often heightened by increasing the disparity between the preshift and postshift components (Flaherty, 1996). This would mean that, for example, a shift from a 10 token schedule to a two token schedule would be expected to produce greater negative contrast than a shift from a 10 token schedule to a five token schedule.

**Anticipatory contrast.** Incentive contrast represents a change in responding due to experiencing a change in reinforcer magnitude. When an organism is repeatedly exposed to reinforcer magnitude changes in a multiple schedule format, however, behavior may begin to change prior to (or in “anticipation” of) the shift in reinforcer magnitude (Flaherty, 1996; Zentall, 2005). Flaherty (1996), for example, describes an experiment wherein rats were repeatedly exposed to a multiple schedule consisting of two components. In the first component, the rats received 3 min of a weak 0.15% saccharin solution (a low magnitude reinforcer). This was then followed by a changeover for half of the subjects to the second component wherein the rats received 5 min access to a 32% sucrose solution (a high magnitude reinforcer). The result was that rats who were exposed to the multiple schedule displayed less consummatory behavior in the first component than did rats who were exposed to the first component alone (i.e., no change in magnitude). This is an example of negative anticipatory contrast in that responding is decreased prior to the changeover from a low magnitude reinforcer component to a high magnitude reinforcer component.
Examples of this change in behavior are abundant in everyday life. An individual, for example, in “anticipation” of a seven-course dinner, may eat a light lunch prior to the dinner. The amount of food available during the seven-course dinner (the second component) does not change as a result of foregoing lunch (the first component). Instead, it can be said that the individual responds to an upcoming shift in reinforcer magnitude by depressing responding in the first component in “anticipation” of the second.

Behavioral contrast. Behavioral contrast, alternatively called simultaneous contrast (Flaherty, 1982) or differential contrast (Zentall & Singer, 2007), is frequently mentioned in the behavioral literature (e.g., Catania, 1998; Cooper et al., 2007; Donahoe & Palmer, 2004). In a typical demonstration of behavioral contrast, an organism is exposed to two different components and the rate of responding in one component is altered through some event (e.g., a schedule change, through an extinction or punishment procedure, etc.). The result is an opposite change in responding in the unchanged component (Catania, 1998).

For example, if problem behavior is maintained in two different locations on the same schedule of reinforcement (e.g., FR10; FR10) similar levels of responding would be expected in both settings. If, however, the response requirement in the first setting is greatly increased (e.g., FR500), or responding in the first setting is placed on extinction and/or punished, the behavior may decrease in the first setting and simultaneously increase in the unchanged setting. This description, of course, is quite similar to findings of research on anticipatory contrast. In fact, if the two settings in the previous example
were constantly presented in a multiple schedule, the behavioral contrast effect may be indistinguishable from anticipatory contrast effect. The primary distinction between the two contrast effects is that in behavioral contrast the two schedules may be randomly alternated and still produce an effect so long as distinct discriminative stimuli are associated with each component (Zentall, 2007).

Recall that the effect found in anticipatory contrast relies on the consistent presentation of components in a multiple schedule. In essence, this allows the organism to “anticipate” the shift in schedule. Without this consistent presentation, an anticipatory contrast effect might not be observed. In behavioral contrast, on the other hand, the organism does not need repeated exposure to a multiple schedule—the components need not directly changeover into one another. Instead, the components may be temporally removed and/or occur in a random fashion and a contrast effect would still be observed. Using this distinction, a man who eats less during dinner due to an upcoming dessert would be described as displaying an anticipatory contrast effect. A man who eats less during dinner in the presence of his physical trainer (i.e., punishment occurs during this component) and subsequently eats more in the trainer’s absence (i.e., the unchanged component) would be described as displaying a behavioral contrast effect.

**Within-trial contrast.** Within-trial (Clement, Feltus, Kaiser, & Zentall, 2000) is the most recent form of contrast to be proposed. This new form of contrast describes an effect wherein a preceding event alters preference for a subsequent stimulus. Furthermore, the preference change is in a direction opposite of preference for the preceding event—a less preferred event *increases* preference for subsequent stimuli.
Although relatively novel in the behavioral literature, this behavior change phenomenon has been researched previously in humans and referred to as cognitive dissonance (Aronson, 1961; Festinger, 1957) or justification of effort (Aronson & Mills, 1959). Cognitive dissonance holds that when individuals experience two simultaneous but incompatible cognitions or thoughts, they experience a state of dissonance or discomfort. These individuals may attempt to relieve this dissonance by changing one cognition (Aronson & Carlsmith, 1963). For example, according to this theory, cognitive dissonance may occur if an individual receives two otherwise identical rewards, but one reward requires little effort to obtain and the other requires a large amount of effort to obtain. Cognitive dissonance would be expected to occur because different effort expenditures yielded identical outcomes. The individual could supposedly alleviate this dissonance by altering one cognition (by, for example, describing the more effortful reward as somehow superior to the less effortful reward).

Although studies on cognitive dissonance have yielded results that support the theory, these studies use human subjects and the theory itself is largely applicable only to humans. It is unclear whether non-humans could be said to have cognitions in any human sense of the term, and to apply the theory of cognitive dissonance to non-humans represents an instance of anthropomorphism. Clement et al. (2000), however, found a behavior change with pigeons similar to the change described in research on cognitive dissonance. This finding with non-humans requires an alternative explanation as it does not require an assumption of changes in cognition. The effect was therefore described as within-trial contrast and a different explanation provided.
In within-trial contrast, the relative preference for a stimulus has an inverse relation with the relative value of the events preceding the onset of that stimulus. In other words, preference for a stimulus increases when that stimulus follows a less preferred event, and decreases when that stimulus follows a more preferred event. In the seminal study on within-trial contrast, Clement et al. (2000) repeatedly exposed eight pigeons to two conditions that differed by the amount of effort required within a trial. In the first condition (see Figure 1.1) the pigeons were exposed to a white center key (Circ) which led into an FR1 schedule that was followed by a two-key discrimination task. During the discrimination task, a peck to the S+ key (red key; $S^{+}_{\text{FR1}}$) resulted in food reinforcement and a peck to the S- key (yellow key; $S^{-}_{\text{FR1}}$) resulted in no food reinforcement. In the second condition, the pigeons were exposed to an identical white center key (Circ) which led into an FR20 schedule followed by a similar two-key discrimination task. This second discrimination task, however, involved different colored S+ (green key; $S^{+}_{\text{FR20}}$) and S- (blue key; $S^{-}_{\text{FR20}}$) than those of the first condition. After repeated exposure to both conditions, preferences for the various stimuli used in the discrimination tasks were assessed. This was accomplished by presenting the $S^{+}_{\text{FR1}}$ and $S^{+}_{\text{FR20}}$ simultaneously and allowing the pigeons to select one key (recall that both S+ had resulted in the same food reinforcement during training). This same preference assessment was conducted for both S-. The authors found that the pigeons consistently preferred the S+ and the S- that had previously followed the high-effort (and therefore presumably low preference) condition (i.e., FR20).
Figure 1.1. Training trials from Clement et al. (2000). A key peck to Circ produced either an FR1 or FR20 schedule followed by discrimination trials. A key peck to either S+ resulted in food reinforcement. A key peck to either S- resulted in no food reinforcement.

The finding that preference for each stimulus was directly related to the amount of effort required to gain access to that stimulus might be described as cognitive dissonance if not for the use of non-human subjects. A more parsimonious explanation of the findings is required and the authors concluded this to be a contrast effect. The behavior change, however, was not the result of a shift in schedule from FR1 to FR20 (as would be required for incentive or anticipatory contrast), nor was it due to a change in one of the schedules of reinforcement (as would be required for behavioral contrast). Additionally, no discriminative stimuli preceded the presentation of either the FR1 or FR20 schedules so it is unclear whether incentive, anticipatory, or behavior contrast would serve as an adequate explanation of the findings. The authors concluded that because the contrast occurred due to the juxtaposition of the effort event and the subsequent discriminative stimuli (i.e., different colored keys), this phenomenon would most appropriately be
described as within-trial contrast (rather than, perhaps, across schedule contrast which might appropriately describe other forms of contrast).

The implications of this finding with non-humans are important for several reasons. First, although the effects of cognitive dissonance (and justification of effort) were found in this study, cognitive dissonance is an inadequate explanation as it relies on the anthropomorphic and unconfirmed assumption that non-humans and humans interpret experiences in a similar fashion. Within-trial contrast may therefore provide a more parsimonious explanation for similar findings with humans (Singer, Berry, & Zentall, 2007). Second, although it has been found that organisms prefer stimuli that predict less rather than more effort (Hull, 1943; Mazur, 2002), it is less obvious whether stimuli that follow less rather than more effort would be preferred. When conditioning a stimulus, it is generally the event that occurs after the stimulus, rather than before, that exerts the most conditioning effect (Mazur, 2002). Within-trial contrast, however, challenges this notion by providing evidence that an event occurring before a stimulus may also have conditioning properties. Third, the finding that non-preferred events can increase the value of subsequent stimuli may lead to behavioral technologies that enable practitioners to better condition stimuli as reinforcers.

Although replications of this phenomenon indicate the behavior change is relatively reliable, there are still lingering questions as to the exact nature and cause of the change in behavior, and whether the change is actually an example of contrast. In addition, although a model of within-trial contrast has been proposed, an alternative model—state-dependent valuation (discussed later in this paper)—has also been proposed.
as an explanation for the findings. Thus, within-trial contrast is an area in need of further investigation.

**Purpose of the Paper**

The purpose of this dissertation is fourfold. First, the literature on within-trial contrast will be reviewed and the results will be discussed in terms of subject type (human vs. non-human) and preceding events. Differences in procedures used across studies will be delineated as will inconsistencies in findings. Second, the current model explaining the within-trial contrast effect will be described. This model will be contrasted with the state-dependent valuation model, which offers an alternative explanation for the within-trial contrast effect findings. The limitations of both models will be described. Third, an alternative explanation of the within-trial contrast findings will be presented. This explanation offers a more parsimonious account of the contrast effect and is supported by current behavior analytic theory. Finally, a study will be described that examines the conditioning effects of preceding events on both preceding and subsequent stimuli (including changes in preference as well as reinforcing value). The results of the study will be discussed in relation to the literature on within-trial contrast, and implications for behavior change technologies will also be discussed.
Chapter 2: Literature Review

Method

To identify articles describing within-trial contrast and state-dependent valuation, two literature searches were conducted using the databases PsycINFO and PubMed. The keywords used were “within-trial contrast” for one search and “state-dependent valuation” for the second. All resulting peer-reviewed articles were retained. Of these articles, a search of the references was conducted and studies that investigated within-trial contrast, state-dependent valuation, or utilized similar procedures were included in the list of articles. Excluded were articles that focused only on cognitive dissonance or justification of effort as these studies did not directly measure preference but rather relied on preference rating scales. The purpose of these search criteria was to identify all articles that specifically demonstrated a change in preference due to preceding events, regardless of the term or model used to describe or explain the findings.

Results and Discussion

Subject Type and Non-preferred Event

In total, 17 articles were found that demonstrated an increase in preference for a stimulus that followed a less rather than more preferred event. Five of these articles investigated the behavioral phenomenon from the conceptual perspective of state-
dependent valuation (Aw, Holbrook, Burt de Perera, & Kacelnik, 2009; Kacelnik & Marsh, 2002; Marsh, Schuck-Paim, & Kacelnik, 2004; Pompilio & Kacelnik, 2005; Pompilio, Kacelnik, & Behmer, 2006); however, because the procedures used in these studies were almost identical to those used to investigate within-trial contrast, the articles will be collapsed into the findings of within-trial contrast. However, both the within-trial contrast and state-dependent valuation models will be discussed separately. Of these 17 studies, 14 successfully demonstrated the effect with various non-humans including pigeons, locusts, grasshoppers, rats, banded tetras, and starlings. The remaining three studies successfully demonstrated the effect with humans, both children and adults.

In addition to replications of the Clement et al. (2000) findings with different non-human organisms, a variety of non-preferred preceding events have been investigated. In experiments with non-humans, a within-trial contrast effect has been seen when the preceding event was high versus low effort (Clement et al., 2000; Clement & Zentall, 2002; Friedrich & Zentall, 2004; Kacelnik & Marsh, 2002), low versus high probabilities of reinforcement (Clement & Zentall, 2002; Gipson, Miller, Alessandri, & Zentall, 2009), long versus short delays to the discrimination tasks (Clement et al., 2000; DiGian, Freidrich, & Zentall, 2004; O'Daly, Meyer, & Fantino, 2005), non-preferred versus preferred schedules of reinforcement (Singer et al., 2007), absence or presence of reinforcement (Friedrich, Clement, & Zentall, 2005), and high versus low states of food deprivation (Aw et al., 2009; Marsh et al., 2004; Pompilio & Kacelnik, 2005; Pompilio et al., 2006; Vasconcelos & Urcuioli, 2008). In each of these cases, preference was increased for stimuli that followed the less preferred event (i.e., high effort, low
reinforcement probabilities, long delays, non-preferred schedules of reinforcement, absence of reinforcement, high states of hunger).

In the three studies to conduct experiments with humans, a within-trial contrast effect has been seen when the preceding event was high versus low effort (Alessandri, Darcheville, Delevoye-Turrell, & Zentall, 2008; Klein, Bhatt, & Zentall, 2005) and a long versus short delay to the discrimination task (Alessandri, Darcheville, Delevoye-Turrell, et al., 2008; Alessandri, Darcheville, & Zentall, 2008).

These replications and extensions of the Clement et al. (2000) study indicate that the preference change phenomenon has generality across both species and procedures. DiGian et al. (2004), for example, organized their procedures identically to Clement et al. (2000). Rather than require the pigeons to engage in some amount of effort expenditure, however, the two components involved either a 0 s or a 6 s delay to the discrimination task. When testing for preference between the S+0s or S+6s, a preference for the S+ that followed the less preferred event was found. Thus, the contrast effect does not appear limited to effort alone, but may be obtained when a variety of non-preferred events precede some stimulus.

**Differences Between Experimental Procedures**

Although many authors replicated the work of Clement et al. (2000), altering only the preferred and non-preferred events, there are some procedural differences among the studies that may be important in understanding the requirements of this specific contrast effect. In addition, although the contrast effect has been repeatedly demonstrated, there
are slight differences between the outcomes that may be related to procedural differences. It is therefore important to examine the different procedures employed in various studies.

The differences in experimental procedures can most easily be examined by conceptualizing the procedures as a chain schedule consisting of three distinct components—(a) the initial link (i.e., the initial discriminative stimulus preceding preferred or non-preferred events), (b) the middle link (i.e., the preferred or non-preferred event), and (c) the terminal link (i.e., the stimulus occurring after the preferred or non-preferred event; the stimulus for which preference is changed). As the middle links have been listed previously in this paper and were the most obvious differences between studies (i.e., generally the most salient independent variable), the following sections will describe procedural differences related to the initial and terminal links only.

**Initial link differences.** In each study, the researchers included at least one preferred and one non-preferred event. It is reasonable to assume that any stimulus that precedes a non-preferred event may become a conditioned aversive stimulus and function as a punisher (Cooper et al., 2007; Mazur, 2006). Because within-trial contrast is presumed to be the result of contrast between the terminal link and the organism’s preference for the middle link, it is necessary to be able to attribute the contrast to those two links alone. If, however, the initial link is also a non-preferred or aversive event, this may confound interpretations of the contrast effect by either adding or subtracting from the effect. It is important, therefore, to distinguish studies that used distinct initial links (i.e., different initial discriminative stimuli) from studies that used identical initial links.
Of the 17 studies examined, five used different initial links (Alessandri, Darcheville, Delevoye-Turrell, et al., 2008; Alessandri, Darcheville, & Zentall, 2008; Clement & Zentall, 2002; Friedrich et al., 2005; Singer et al., 2007), four used identical initial links (Clement et al., 2000; Gipson et al., 2009; Kacelnik & Marsh, 2002; Klein et al., 2005), and three used both distinct and identical initial links for different groups (DiGian et al., 2004; Friedrich & Zentall, 2004; O'Daly et al., 2005). The five studies that tested different states of hunger (Aw et al., 2009; Marsh et al., 2004; Pompilio & Kacelnik, 2005; Pompilio et al., 2006; Vasconcelos & Urcuioli, 2008) did not include initial links because it is not feasible to have an initial link lead directly into a state of hunger without a prohibitively long duration between the initial and middle links.

Whether an initial link influences the contrast effect is currently unclear. DiGian et al. (2004) used different initial links (vertical and horizontal lines) for one group of pigeons and identical initial links (white keys) for a different group of pigeons. Thus the first group of pigeons could discriminate upcoming events but the second group could not. Although both groups significantly preferred the stimulus that followed longer delays, the group that experienced different initial links (i.e., could discriminate upcoming events) displayed a greater degree of contrast than the undifferentiated initial link group. This may indicate that the degree to which an initial link functions as an aversive stimulus (i.e., is predictive of a worsening of upcoming events) may have some impact on the degree of positive or negative contrast.

O’Daly et al. (2005), on the other hand, compared distinct versus identical initial links for different groups of pigeons and found that levels of contrast were equal
Regardless of initial link. Interpretation of these different findings is complicated by the fact that both studies differed procedurally in terms of terminal links (discussed below) and this may have influenced outcomes in ways unrelated to initial links. Nevertheless, there is at least some evidence that the initial link influences the formation of within-trial contrast and that the effect may not be due to the middle link alone. The extent to which pairing the initial link with the middle link alters preference for the initial link or for conditions that link as an aversive event has yet to be determined.

**Terminal link differences.** The terminal link stimuli were those stimuli which followed the middle link and preference for these stimuli was expected to alter based on the specific middle link. The presentation of these stimuli varied among studies primarily based on whether the researchers presented a single stimulus after each condition, or presented two stimuli together in a discrimination task. In nine of the 17 studies, a discrimination task was presented following the middle link (Alessandri, Darcheville, Delevoye-Turrell, et al., 2008; Alessandri, Darcheville, & Zentall, 2008; Clement et al., 2000; Clement & Zentall, 2002; DiGian et al., 2004; Friedrich et al., 2005; Gipson et al., 2009; Klein et al., 2005; Singer et al., 2007). In these studies, subsequent to exposure to the middle link the researchers presented two distinct stimuli (e.g., different colored keys, different shapes, etc.) and the organism was required to select one stimulus. The stimuli used in each discrimination task differed based on whether the middle link was preferred or non-preferred; however, in both discrimination tasks the S+ resulted in some additional reinforcement and the S- resulted in no reinforcement. After training, the contrast effect was assessed by allowing a free choice between the two S+ that followed
preferred and non-preferred events (S+\text{preferred} and S+\text{non-preferred}), and between the two S- that followed those same events (S-\text{preferred} and S-\text{non-preferred}). According to the within-trial contrast model, subjects should display preference for S+\text{non-preferred} and S-\text{non-preferred} (i.e., both stimuli that followed non-preferred events) over S+\text{preferred} and S-\text{preferred}.

Studies employing a discrimination task in the terminal link have produced conflicting results. Some studies have shown that the S+\text{non-preferred} and S-\text{non-preferred} are equally likely to become more preferred (Clement & Zentall, 2002; Gipson et al., 2009; Singer et al., 2007) and Clement et al. (2000) found an even greater preference for S-\text{non-preferred}. This indicates that both S+ and S- (i.e., stimuli that are and are not associated with reinforcement) are more preferred when they follow non-preferred events than S+ or S- that follow preferred events. These findings provide strong evidence that it is preference for the preceding event that is responsible for the contrast effect rather than the events that follow the terminal link (i.e., reinforcement or no reinforcement).

Other research, however, has either demonstrated that a contrast effect is weaker with the S-\text{non-preferred} than with the S+\text{non-preferred} (Friedrich et al., 2005) or have shown that a contrast effect is not found at all with the S-\text{non-preferred} (Alessandri, Darcheville, & Zentall, 2008; Clement & Zentall, 2002; DiGian et al., 2004; Klein et al., 2005). These results are difficult to interpret. On the one hand, a within-trial contrast effect should be expected to occur with both S+ and S- because they are both contrasted with the middle link. That selection of the S+ is followed by reinforcement should result in preference for the S+ over the S-, but the S- that follows a non-preferred event should still be preferred more than an S- that follows a preferred event. This increase in preference, however, is
not seen in these studies and this may indicate that the reinforcement that follows the S+ is somehow a necessary component in the development of contrast.

If this is the case, however, it is unclear why it would be necessary to invoke within-trial contrast as an explanation for the change in preference. Instead, a more parsimonious explanation would be that preference was increased for the S+ because it was followed by a reinforcing event. Preference for the S- did not change because it was followed by no event. This finding, of course, is simply a demonstration of reinforcer conditioning and has been noted extensively in the behavioral literature (e.g., Cooper et al., 2007; Skinner, 1960).

An alternative explanation, however, might be that in order for contrast to develop the organism must respond to the stimulus that follows the middle link. Because the S+ and S- were presented in a discrimination task, the organism learned to consistently select the S+ stimulus while avoiding the S-. It may be that the presentation of stimuli in a discrimination task enables the formation of a contrast effect with the S+ but inhibits the development of a contrast effect in the other stimulus. Currently, it is unclear whether this is the case or whether the addition of reinforcement after a terminal link is somehow necessary in the development of within-trial contrast.

More straightforward examples of the contrast effect are evident in the eight studies that did not require the organism to engage in a discrimination task in the terminal link (Aw et al., 2009; Friedrich & Zentall, 2004; Kacelnik & Marsh, 2002; Marsh et al., 2004; O'Daly et al., 2005; Pompilio & Kacelnik, 2005; Pompilio et al., 2006; Vasconcelos & Urcuioli, 2008). In these studies the organism was simply exposed to the
middle link and then exposed to the terminal link which was a single stimulus (e.g.,
colored key) that was different for preferred and non-preferred events. After training, the
organism was presented with both stimuli simultaneously. In each of these studies a
significant preference was found for the stimulus that had previously followed non-
preferred events.

**Failures to Replicate**

Although the original findings of Clement et al. (2000) have been replicated by
different researchers and with different types of preferred and non-preferred events, there
have been seven studies that failed to replicate the results (Arantes & Grace, 2008;
Armus, 2001; Jellison, 2003; Vasconcelos & Urcuioli, 2008, 2009; Vasconcelos,
Urcuioli, & Lionello-DeNulf, 2007; Waite & Passino, 2006). Explanations for these
failures to replicate have been numerous and have included assertions that the contrast
effect is slow to develop (Singer et al., 2007), that overtraining is required to achieve a
contrast effect, that the terminal link must be contiguous with the middle link, or that a
subject’s previous experiences with particularly lean schedules of reinforcement may
decrease the development of a within-trial contrast effect (Zentall, 2008).

For each suggested reason for a failure to replicate, however, there is at least one
study that demonstrates the reason to be insufficient. First, Arantes and Grace (2008)
provided an amount of training equal to that used in other successful studies, and
Vasconcelos and Urcuioli (2009) provided extensive overtraining, yet both experiments
failed to produce reliable results. This seems to negate the suggestion that a failure to
replicate was due to a lack of overtraining. Second, a within-trial contrast effect has been
demonstrated with a long delay as the non-preferred event (e.g., Alessandri et al., 2008), and this would seem to invalidate the argument of a lack of contiguity between middle and terminal links. Finally, researchers such as Vasconcelos and Urcuioli (2007) utilized experimentally naïve pigeons and employed overtraining but still failed to replicate previous findings. As these pigeons did not have previous exposure to a lean schedule of reinforcement (which would presumably make high effort less aversive), the suggestion that this failure to replicate was due to previous experience with lean schedules seems doubtful.

There are other possible explanations for some failures to achieve within-trial contrast in some studies. Armus (2001) and Jellison (2003), for example, conducted experiments using two differently flavored pellets (grape and bacon flavored) as terminal links following different amounts of effort. Although initial tests demonstrated no preference for either flavored pellet prior to the experiment, it is possible that preferences developed based on repeated exposure to the food throughout the experiment (Wardle, Herrera, Cooke, & Gibson, 2003). It is then difficult to determine whether the results of these two experiments represent a failure to replicate, or rather that a contrast effect was masked by an increase in food pellet preference independent of the middle link.

For some studies (e.g., Armus, 2001; Jellison, 2003) it is plausible that procedural differences are responsible for failures to replicate the original findings of Clement et al. (2000). The reasons for the remaining failures to replicate remain unclear given that the procedures employed were all quite similar. Despite some failures to replicate the within-trial contrast effect, the large number of studies that were able to reproduce the
results of Clement et al. (2000) suggest that the original findings are valid and not the result of a Type I error (i.e., finding an effect where there is none).

**Procedural Problems with Reviewed Studies**

The effect of within-trial contrast is purportedly to differentially alter preference for stimuli (terminal links) that follow differentially preferred events (middle links). To that end, it is highly important that preference for both the terminal and middle links be established prior to demonstrating a change in either event. Surprisingly, however, this was seldom done in any of the 24 reviewed articles (including both replications and failures to replicate). This failure in assessment may help explain the different results achieved by different researchers.

In within-trial contrast, preference for a terminal link is determined by whether it follows a preferred (e.g., low effort, short delay, etc.) or non-preferred (e.g., high effort, long delay, etc.) middle link. It is important, therefore, to first establish the extent to which the two middle links are differentially preferred. Of the 24 articles reviewed, however, only three (Alessandri, Darcheville, Delevoye-Turrell, et al., 2008; Friedrich & Zentall, 2004; Singer et al., 2007) measured preference for the middle links. Furthermore, Friedrich and Zentall (2004) did not measure middle link preference until after the subjects had completed training. The extent to which ending middle link preference is representative of beginning middle link preference is unknown.

It may be tempting to assume that more effort or longer delays will always be less preferred events by all organisms. Whether an event will be preferred or non-preferred however, is specific to the individual organism and it cannot be assumed that some events
will be uniformly non-preferred by all participants. For example, Alessandri, Darcheville, Delevoye-Turrell, and Zentall (2008) employed middle links that required participants to press a button with varying amounts of force and for varying lengths of time. It might be assumed that participants would prefer less effort and short lengths of time. Although this was generally true, for two participants this was not the most preferred middle link. During training, each participant was exposed to the most and least preferred middle links that were specific to that participant. Thus, changes in terminal link preference could be linked directly to preference for middle link events. Had the researchers simply relied on an assumption of preference (as did most other researchers), terminal link preference changes for these participants would be difficult to interpret. As mentioned previously, an increase in preference for a terminal link that followed a preferred middle link would not be surprising. If this preferred middle link had been erroneously assumed to be non-preferred, a contrast effect would be indicated where none actually existed.

An even larger problem than an assumption of preference for middle links, however, is that none of the 24 reviewed studies assessed preference for terminal links prior to exposing the organism to the training condition. As the primary measure when demonstrating the within-trial contrast effect is differential preference between terminal links, it is paramount that researchers establish initial preference. The various terminal links used in different studies included stimuli such as different random shapes, different colors, or different orientations of lines, but whether these stimuli were equally preferred prior to training was never tested. Without knowing initial preference, it is difficult to
determine the impact of the contrast effect. If preference was initially low and was shifted to high, this would indicate a very strong contrast effect. If, on the other hand, preference was initially somewhat high and was shifted higher, this would indicate a fairly weak effect.

**Different Models Explaining the Effects**

Two models have been proposed to explain the effects found in the reviewed studies. The two models will be briefly described and the limitations associated with each model will be identified. Finally, a third model will be provided that remedies the limitations of the two current models and provides a more behavior analytic interpretation of the effects.

**The Within-trial Contrast Model**

The current model explaining the within-trial contrast effect (see Figure 2.1) was first proposed by Clement et al. (2000) and has since been refined to include findings related to non-preferred conditions other than effort. The general model assumes that prior to exposure to a preferred or non-preferred event the organism exists in some hedonic state or general state of wellbeing. When an organism is exposed to a non-preferred event there is a negative change in the organism’s hedonic state (\(H-\Delta H\)) and this negative change is directly proportional to the degree to which the event is non-preferred. A highly non-preferred event (e.g., FR20) is assumed to result in a greater negative shift in hedonic state whereas an event that is only slightly non-preferred (e.g., FR1) is assumed to result in a slight negative shift. When a reinforcing stimulus is presented at the end of the event, there is a positive shift in the hedonic state of the organism, and the
ending hedonic state is equal regardless of previous hedonic state. The contrast, then, is between the organism’s hedonic state before and after the presentation of the reinforcing stimulus. The degree to which preference is changed depends on the amount of positive shift in hedonic state and therefore also on the degree to which an event is non-preferred (compare relative values in Figure 2.1).

In the original experiment demonstrating the within-trial contrast effect (Clement et al., 2000) a pigeon was exposed to two different schedules of reinforcement (i.e., FR1 or FR20) and then presented with the terminal stimulus. According to the within-trial contrast model, because the effort expended under the FR20 schedule was greater than the effort expended under the FR1 schedule, exposure to the FR20 schedule resulted in a greater negative shift in hedonic state. This would also mean that the presentation of the terminal link (a colored key; Reinf in Figure 2.1) resulted in a greater positive shift in hedonic state when it followed the FR20 schedule than when it followed the FR1 schedule. This is because the end hedonic state is assumed to be equal regardless of the hedonic state at the moment the terminal link is encountered. The difference in hedonic state change, therefore, is greater when the hedonic state is initially low (i.e., following exposure to a highly non-preferred event). Although this model was originally proposed to explain changes in preference when the non-preferred event was high effort, a greater negative change in hedonic state is also assumed when the organism is exposed to longer delays to the terminal stimulus, less preferred schedules of reinforcement, or when the organism is in a state of hunger.
Figure 2.1. “A model based on change in relative hedonic value, proposed to account for within-trial contrast effects. According to the model, trials begin with a relative hedonic state, H; key pecking results in a negative change in hedonic state, H-ΔH₁ for FR1 and H-ΔH₂₀ for FR20; obtaining a reinforcer results in a positive change in hedonic state, H+ΔH_{Rf}; the net change in hedonic state depends on the difference between H+ΔH_{Rf} and H-ΔH₁ on an FR1 and between H+ΔH_{Rf} and H-ΔH₂₀ on an FR20 trial.” (Zentall, 2005, p. 280).

Limitations of the within-trial contrast model. There are several problems with the within-trial contrast model proposed by Clement et al. (2000). First, in providing an explanation for the contrast effects, the model assumes a hedonic state and uses changes in this hedonic state (both absolute and relative) as the primary events responsible for contrast. Hedonic state, however, is a term that only vaguely refers to an organism’s wellbeing and there is currently no agreed upon definition (Pompilio & Kacelnik, 2005). Hedonic state seems to function much the same as a hypothetical construct. There is no
method of objectively determining an organism’s hedonic state, much less detecting changes in that state.

The concept of hedonic state appears most useful primarily when inferring different states of hunger. It is possible, for example, to bring a pigeon to 70% of free weight and infer that the pigeon is hungrier (and therefore in a greater negative hedonic state) at 70% free weight than at 100% free weight. This concept is less applicable or measureable, however, when referring to changes that occur within an organism as a result of being required to peck a key 19 additional times or to wait an additional 30 s for a reinforcer. Although the term hedonic state and assumptions of changes in this state may be convenient, it is unclear whether hedonic state refers to any measurable state of being.

A second and much larger problem with the current within-trial contrast model is that the model assumes that the end hedonic state of the organism (i.e., the state after terminal link presentation; Reinf. in Figure 2.1) is equal regardless of the previous hedonic state. Thus, the end hedonic state of the organism after reinforcement is assumed to be the same regardless of whether the middle link was FR1, FR20, or FR1000. The entire within-trial contrast model rests on this assumption, and contrast is assumed to occur because a more negative hedonic state allows for greater differences in upward shifts and thus greater differences in the relative values of reinforcers.

Assuming that the value of a reinforcing stimulus is relative to other events, as opposed to being absolute, is not a new concept. In 1738, in discussing price versus value, Daniel Bernoulli wrote that “the price of the items is dependent only on the thing
itself and is equal for everyone; the utility, however, is dependent on the particular circumstances of the person making the estimate. Thus there is no doubt that a gain of one thousand ducats is more significant to a pauper than to a rich man though both gain the same amount.” (as cited in Bernoulli, 1954, p. 24). Although it may be true that the relative value of one thousand ducats is greater to a pauper than a rich man, this is not the same as saying that both individuals will achieve the same end state if given the same amount of ducats; the rich man will be slightly richer but the pauper will now have only one thousand ducats. An equal end hedonic state, however, is the assumption made by the current within-trial contrast model.

This flawed logic is most easily seen when applied to effects found with different states of hunger (the most reliable effects found). If a pigeon is always given two red food pellets when in a state of extreme hunger (an ostensibly highly negative hedonic state), and always given two blue food pellets when in a state of near complete satiation (an ostensibly slightly negative hedonic state), we would expect to find during later testing that the pigeon prefers red food pellets regardless of current hunger level. This essentially was the finding of researchers such as Pompilio and Kacelnik (2004) and Pompilio et al. (2006). Although we might say that the pigeons were in different states of hunger and therefore assume different hedonic states, it is doubtful whether an extremely hungry pigeon and a near satiated pigeon immediately achieve the same state of hunger after ingesting two food pellets. Most likely, the extremely hungry pigeon is only slightly less hungry and the near satiated pigeon is now completely satiated. With this understanding, then, the within-trial contrast model would look more similar to Figure
2.2. In this new model, however, contrast would not be expected to occur because the upward shift in hedonic state was equal for both states of hunger and contrast could occur only if the relative values were unequal.

Figure 2.2. Within-trial contrast model assuming the end hedonic state is not equal after reinforcer presentation but rather dependent on current state.

A third problem with the within-trial contrast model is that the model describes an upward shift in hedonic state as the result of the presentation of a reinforcer after a non-preferred event. Recall, however that several researchers used a discrimination task as the terminal link and found an effect with both the S+ and S- (Clement et al., 2000; Clement & Zentall, 2002; Gipson et al., 2009; Singer et al., 2007). In these discrimination tasks, the S+ was associated with the delivery of a reinforcer, and thus it is
feasible that the S+ could result in an upward shift in hedonic state. The S-, however, was never associated with a reinforcer and thus should not increase hedonic state. Yet in these studies an effect was found with the S- and in one case (Clement et al., 2000) the contrast effect was greater with the S-. If it is the delivery of a reinforcer that increases hedonic state, a contrast effect should not be seen with any S- as this stimulus is never associated with reinforcement and should therefore not function as a reinforcer.

The current within-trial contrast model is an inadequate explanation for the various findings with different organisms and with different non-preferred events. The model relies not only on an immeasurable hedonic state (already a hypothetical construct with no clear definition) but also on the assumption that the end hedonic state achieved through access to a reinforcer is equal regardless of the state of the organism immediately prior to reinforcer delivery. In addition, a contrast effect has been demonstrated with stimuli that are not associated with reinforcement and which should therefore not increase hedonic state. Although the current within-trial contrast model allows researchers to predict how an organism’s preference will change, these problems make the current model less than ideal in providing a scientific explanation of the contrast effects achieved in the previously described studies.

The State-dependent Valuation Model

Kacelnik and Marsh (2002) proposed state-dependent valuation as an alternative model to explain the same within-trial contrast phenomenon without relying on the assumptions made in the within-trial contrast model. The state-dependent valuation model hypothesizes that the relative value of a reinforcer is directly related to the
energetic state or fitness of the organism at the point of reinforcer delivery. A reinforcer that is delivered at a point of low energy reserves is assumed to be relatively more valuable than that same reinforcer delivered at a point of higher energy reserves. The assumption is that when an organism is required to expend some amount of energy (such as through key pecking or repeated flight) the energetic state of that organism is lowered. This is much the same idea as the negative shift in hedonic state assumed in within-trial contrast models (although perhaps more measurable than the concept of hedonic state). A reinforcer that is encountered in a low energetic state would have more value in terms of *fitness* or *utility* precisely because it comes at a time of low energy reserves.

Importantly, this model does not assume that the delivery of a reinforcer increases an organism’s energetic level to the same state regardless of starting point (as does the within-trial contrast model). Under this model, if Pigeon A was in a very low energetic state but Pigeon B was in a high energetic state and both were given two food pellets, Pigeon A would still be in a lower energetic state than Pigeon B, but the fitness or utility value of the two food pellets would be greater for Pigeon A. The model further assumes that with repeated exposures to a specific food item under states of low energy reserves, the utility value of the food item is somehow represented in memory (Pompilio & Kacelnik, 2005) and thus of more value when encountered under any future energetic state (either low or high).

Although both the state-dependent valuation model and the within-trial contrast model make similar predictions and are based on the same data sets, the benefit of the state-dependent valuation model is that it does not require the assumption that an
organism’s state after receiving a reinforcer is the same regardless of starting point. Particularly when preference changes are due to middle links consisting of different states of hunger or energy reserves, it seems unlikely that the within-trial contrast model can provide an adequate description of the phenomenon. The state-dependent valuation model provides a better explanation in these instances.

**Limitations of the state-dependent valuation model.** Although the state-dependent valuation model resolves some of the problems associated with the within-trial contrast model, there are several problems that arise when attempting to apply the model to all instances of preference change reviewed in this paper. First, although state-dependent valuation assumes that the function of the middle links is to differentially depress energy reserves, it is unclear whether this is always the case. Although plausible when the middle links are different states of hunger, this assumption seems less logical when applied to middle links that would not be expected to deplete energy reserves such as different delay lengths (DiGian et al., 2004) or different schedules of reinforcement (Singer et al., 2007). DiGian et al. (2004), for example, were able to successfully alter preference in favor of terminal links that followed a 6 s delay rather than a 0 s delay. It is unclear whether this finding is best explained by assuming that a 6 s delay sufficiently depressed the energy reserves of pigeons to such an extent that two different terminal links would have differential fitness value. This same argument could be applied to studies that used different schedules of reinforcement (e.g., FI; DRO) as middle links while holding total reinforcement constant (Singer et al., 2007).
A second problem with the state-dependent valuation model is that several studies have shown changes in preference when the terminal links were stimuli that may have had little effect on energetic state. Alessandri et al. (2008) for example, provided children with short song segments or segments of a cartoon upon successful discrimination in the terminal link. Similarly, Klein et al. (2005) had a computer screen display the words “correct” or “incorrect” during discrimination. To apply the state-dependent valuation model to these studies would be to assume that somehow access to a cartoon or the word “correct” functioned to increase energetic states previously depressed through exposure to the middle link and this is doubtful the case. Furthermore, as noted in the limitations of the within-trial contrast model, an increase in preference has been observed with S- in terminal link discrimination tasks. As these stimuli are not associated with any reinforcement, it is unclear how they would increase an organism’s energetic state. Thus, it appears that for some of the middle and terminal links that have been investigated, the state-dependent valuation model provides an insufficient explanation.

**Alternative Explanation**

In order to remedy the problems associated with the within-trial contrast model (i.e., use of a hypothetical construct, assumption of equal ending hedonic states, findings with S-) and problems associated with the state-dependent valuation model (i.e., reliance on energetic state loss and relative gain), I propose a third explanation that incorporates the concepts of motivating operations and negative reinforcement. The proposed explanation along with its limitations will be described below.
According to Michael (2004) “an establishing operation [or motivating operation] . . . is an environmental event, operation, or stimulus condition that affects an organism by momentarily altering (a) the reinforcing effectiveness of other events [the value-altering effect], and (b) the frequency of occurrence of the type of behavior that had been consequated by those other events [the behavior altering effect]” (p. 136). A motivating operation (MO) may be distinguished from a discriminative stimulus (SD) by its function. Whereas an SD indicates the differential availability of some consequence, an MO is not associated with differential availability of consequences but rather momentarily alters the value of the consequence and the likelihood of behaviors that have functioned to produce that consequence. These two functions of an MO are known as the value-altering and behavior-altering effects (Cooper et al., 2007).

The different effects of the SD and the MO may be seen in the following example:
A man is driving in a car and listening to the radio. Although the radio had been playing at a reasonable volume, a loud and particularly obnoxious commercial comes on the air, and the man turns down the volume. When the commercial ends, the man finds that he cannot hear the music and once again turns the volume up to the previous level. In this scenario, it would be tempting (but incorrect) to say that the loud commercial functioned simply as an SD and the response (turning the radio down) was reinforced through lowered volume. This is incorrect because a lowered volume is equally available with and without the presence of the loud commercial. The commercial did not differentially signal the availability of lowered sound and cannot, therefore, be considered to simply be an SD. Instead, it would be more correct to say that the loud commercial functioned as an
MO and altered the value (not the availability) of lowered sound. In addition, the loud commercial altered the likelihood of behaviors that had previously been consequated with lowered sound (i.e., turning down the volume). Essentially, the function of the loud commercial, in this example, was to establish itself as a negative reinforcer and its removal as a reinforcing event (in this case, negative reinforcement). When the music was too quiet, the function was to establish louder music as a reinforcing event and increase behaviors that had previously been consequated with louder volume (i.e., turning up the volume).

Let us now apply the MO explanation to the procedural setup of the within-trial contrast studies. In a typical study on effort, for example, a pigeon might be exposed to both of the following components in an alternating fashion.

- **Component 1:** Initial link 1 $\rightarrow$ middle link 1 (FR5) $\rightarrow$ terminal link 1 (red key)
- **Component 2:** Initial link 2 $\rightarrow$ middle link 2 (FR30) $\rightarrow$ terminal link 2 (blue key)

In both components, engaging in the initial link produces differential effort outcomes—low effort (FR5) or high effort (FR30). Presumably repeated exposure to both of these components would condition initial link 2 as both an S\textsuperscript{D} and an aversive stimulus in that it is followed by more effort than initial link 1. After the initial link, the pigeon is then exposed to either high effort (FR30) or low effort (FR5). Assuming that the pigeon would prefer not to engage in any effort expenditure, both middle link 1 and 2 may be considered motivating operations in that they both function to increase the value of stimuli that signal the termination of the middle link. However, due to differences in the magnitude of the required effort in both events, middle link 2 (FR30) is more aversive.
than middle link 1 (FR5). Any stimulus that terminates middle link 2 should be valued more than any stimulus that terminates middle link 1. This would mean that terminal link 2 should be valued more than terminal link 1 as terminal link 2 coincides with the termination of the more aversive event. The entire procedure, therefore, has served to expose the pigeon to a chain schedule involving an aversive stimulus (middle link), and to associate the termination of that stimulus with the presentation and selection of another stimulus (terminal link).

In conditioning positive reinforcers using chain schedules, it has previously been noted that the terminal link of a chain schedule may become a conditioned reinforcer because it is consistently contiguous with the primary reinforcer occurring at the end of the chain (Fantino, 1977). The explanation described here asserts that the same effect occurs in these chain schedules except that the terminal link becomes a conditioned reinforcer not through contiguity with the positive reinforcer (recall that in some studies with discrimination terminal links subjects also preferred the S_{non-preferred}) but through contiguity with the termination of the non-preferred event. In essence, the assumption here is that a stimulus that terminates an aversive event is a reinforcer and the more aversive the event terminated, the more valuable the stimulus.

The explanation proposed here is more parsimonious than the state-dependent valuation model primarily because it does not require an assumption that some events (e.g., 6 s delays; DRO versus FI schedules) function to decrease an organism’s energy reserves to such a degree that two stimuli would have different utility or fitness value.
Additionally, it does not require an assumption that the presentation of cartoons or affirmations function to increase an organism’s biological fitness.

This proposed explanation is also more parsimonious than the within-trial contrast model because it is able to specify the precise mechanism responsible for altering preference (i.e., motivating operations) as opposed to relying on a hypothetical and undefined construct (i.e., hedonic state). Furthermore, this explanation does not require the assumption that a terminal link leaves the organism in the same state regardless of previous state. On the contrary, this explanation is unconcerned with the state of the organism after the presentation of the terminal link. This explanation assumes a change in preference for the terminal link regardless of ending state so long as the terminal link is associated with the termination of the middle link and does not predict a worsening of events.

Limitations of the alternative explanation. The major limitation of this explanation is that it assumes that some MO is in effect, and directing preference, during the testing phase. In the studies reviewed in this paper, during training the organism was exposed to preferred and non-preferred events that could be conceptualized as establishing their removal as reinforcement. During the testing phases, however, the organism was typically exposed to the two terminal links in the absence of the middle links, and thus in the absence of the previously present MO (the middle links). As the effects of MOs appear to be momentary (Michael, 2004) but the effects found in these studies do not appear to be momentary (i.e., preference is conditioned), this appears to be a limitation of the proposed explanation.
One way this limitation could be ameliorated is by assuming that there is some MO present and guiding choices during the testing phase, but that this MO was not controlled for by researchers. A reflexive MO (Michael, 2004), for example, refers to a stimulus condition that is associated with an improving or worsening of events. A stimulus that in the past has been predictive of a worsening of events may function as a reflexive MO and increase responding. In Clement et al. (2000), for example, a peck to either the S+ or S- during the terminal link produced either reinforcement or no reinforcement (depending on the key pecked). In addition, however, a peck to either terminal link also initiated a 6 s intertrial interval. Thus, a peck during the terminal link temporarily removed the aversive middle link, but also resulted in the presentation of the initial link 6 s afterwards. Simultaneous presentation of the two terminal links during testing could have functioned as an aversive event by signaling upcoming non-preferred events (i.e., future trials). This aversive event may have functioned as an MO by altering the value of the two terminal links and evoking behavior that had previously been associated with terminating the aversive event (i.e., selecting the terminal link that previously removed the more aversive events). If this were the case, it could be argued that an MO was present during the testing phase and that this MO guided selection between the terminal links.

Some support for this assumption is provided by Clement et al. (2000) who tested preference for terminal links under three conditions: following low-effort (i.e., FR1), following high-effort (i.e., FR20), and following no prior stimulus. The researchers found that regardless of the event occurring prior to the terminal link during testing, the
pigeons consistently chose the terminal link that had followed high-effort during training. Alessandri et al. (2008) found similar results when testing under conditions of no delay, delay, and no prior stimulus. These findings demonstrate that even when exposed to an event that is only slightly non-preferred, an organism will still choose the stimulus that is associated with the termination of highly non-preferred events. Assuming that the presentation of the two terminal links alone in testing does constitute a small aversive event, the findings that organisms prefer stimuli associated with the termination of more effort, long delays, and no reinforcement, is expected.

It is reasonable to assume that there is always some motivation at play whenever a response occurs. When two terminal links are presented in a choice format, the motivation must only be high enough to shift preference towards one of two stimuli. If no motivation existed for one terminal link over the other, an organism’s responding would be expected to be equally distributed between the two stimuli. The finding, however, that responding is not equally distributed indicates that some motivation exists that increases responding towards a specific stimulus. The explanation offered here outlines the method by which this motivation is conditioned and provides an account as to why stimuli that follow aversive events are preferred over those that follow less aversive events.

**Conclusion**

The findings of the studies reviewed in this paper, along with the alternative explanation provided of those findings, have important implications for behavior analysis. The first implication is in regards to the creation of behavioral programs
designed to alter behavior. Whenever behavior change interventions are created, consequences are selected for their function on behavior and programmed to be delivered after an organism’s engagement in some amount of behavior. Although much attention is given to the effect a consequent stimulus has on an organism’s engagement in an activity, very little attention is given to the effect engagement in an activity has on the value of the consequent stimulus. The studies on within-trial contrast and state-dependent valuation indicate that the interaction between engagement in an activity and a consequent stimulus is not a one-way street with the effect being only that of the consequent stimulus on the activity. Instead, although the consequent stimulus alters the probability of engagement in an activity, the activity simultaneously alters the value of the consequent stimulus. Care, therefore, may need to be exerted when selecting and delivering reinforcement.

When attempting to increase behavior, for example, depending on the degree to which the target behavior is preferred or non-preferred, the subsequent value of the reinforcer is being increased or decreased. Praise that follows a high-effort activity would be expected to increase in value compared to praise that follows a low-effort activity. An A in advanced physics would be expected to be valued more than an A in study hall even though the absolute value of the two grades is identical. It is possible, therefore, for a preferred stimulus that is frequently delivered after highly preferred events to lose its value and cease to be an effective consequence. As opposed to being concerned only with the effect of a consequence on behavior, the effect of behavior on the value of the consequence should also become an area of investigation.
A second implication of these findings and the explanation offered is related to the current understanding of motivating operations. The theory of MOs asserts that the value-altering effect of an establishing operation would be “an increase in the current effectiveness of some stimulus, object, or event as reinforcement” (Cooper et al., 2007, p. 376, emphasis added). It is assumed that hunger, for example, serves to momentarily increase the effectiveness of food as a reinforcer. Both the within-trial contrast and state-dependent valuation models, however, suggest that the state (either hedonic or energetic) of the organism at the time the food stimulus is delivered has a direct conditioning (rather than simply a momentary value-altering) effect on the value of the food stimulus. Although the models themselves have flaws, the findings of the associated studies provide some evidence for the existence of a conditioning process.

Under the current understanding of MOs, if a child is given a red M&M when extremely hungry and a blue M&M when only slightly hungry, at a later point, both M&Ms should function equally well as reinforcers because their value is momentarily altered equally by any given level of hunger. The findings of the reviewed studies, along with the third explanation proposed, however, suggest that at any future state of hunger, the red M&M should have more value relative to the blue M&M, and would function more effectively as a reinforcer. The function of an MO, then, may be to momentarily increase the value of certain stimuli, but also to condition those stimuli as more effective reinforcers. If this is indeed the case, it would mean that the effect of an MO is far less momentary than once thought. Although there is evidence that the state of the organism
at the moment of reinforcer delivery has a conditioning effect on that stimulus, there appears to be no such description in the literature on motivating operations.

A final implication concerns whether contrast is responsible for the results found in the studies reviewed in this paper. With motivating operations, the value-altering effect increases or decreases the reinforcing effectiveness of a stimulus. The value-altering effect of a high effort middle link, for example, is to increase the value of the terminal link. The value-altering effect does not, however, require that a comparison be made between the state of the organism pre and post exposure to the terminal link, which is an assumption of the within-trial contrast. To say that the middle link increases the value of the terminal link is not the same as saying that the middle link is compared with the terminal link and the value is derived from a contrast between the two. If the MO explanation offered in this paper is accurate, and the change in preference is due to the value-altering effect, the implication is that contrast is not responsible for the change in preference.

**Future Directions**

Whether considered a result of motivating operations, within-trial contrast, or state-dependent valuation, the finding that non-preferred events alter preference for subsequent stimuli warrants further inquiry. This finding may indicate the presence of a conditioning process not previously explored in great detail and may suggest augmentation of the current understanding of motivation operations. This finding may also offer a more parsimonious explanation than other psychological theories explaining similar findings (e.g., cognitive dissonance, justification of effort, learned
industriousness, etc.). Future research into the effect preceding events have on subsequent preference may help explain how stimulus preferences develop with greater precision than is currently available, and may allow for a greater understanding of how the environment and behavior interact and impact one another.

Although there have been numerous demonstrations of a change in preference for stimuli that follow non-preferred events, the research in this area suffers from several consistent procedural shortcomings. First, very little attention has been paid to determining preference for either the middle or terminal links prior to exposing a participant to training. In order to make the determination that a change in preference for some stimulus is related to differential preferences for preceding events, it is necessary to initially measure preference for both events prior entering the training condition. Establishing these measures will increase confidence that changes in preference for the terminal links can be attributed solely to differential preferences for the middle links.

Second, it is important that preference changes for the initial links be documented in relation to the subsequent middle link. Particularly when the initial links are dissimilar, it is likely that preference decreases for initial links that lead into non-preferred middle links and increases for initial links leading to preferred middle links. Additionally, as discussed earlier in this paper, it is possible for an organism to display differential preference for initial links prior to training and for this differential preference to either contribute to or diminish the effect of the middle link on the terminal link. Documenting preference for initial links will (a) provide further evidence that a middle link is preferred or non-preferred, (b) allow the effects of the initial and middle links on
the terminal link to be separated, and (c) allow for a more complete picture of the effect a preferred or non-preferred middle link has on preceding and subsequent stimuli.

In addition to assessing preferences for different events/stimuli prior to training, future research should identify whether a non-preferred event not only increases preference for subsequent stimuli but whether it also conditions those stimuli as reinforcers. Although there is often a link between preference and reinforcing effectiveness, it is possible for an organism to display differential preference for stimuli that function equally as reinforcers (Higbee, Carr, & Harrison, 2000; Lee, Yu, Martin, & Martin, 2010). Although the research on within-trial contrast and state-dependent valuation has demonstrated the development of differential preferences for stimuli, no research has documented whether those stimuli come to function differentially as reinforcers. Particularly from an applied standpoint, determining whether those stimuli function differentially as reinforcers is perhaps more important than whether they are more or less preferred. A finding that the procedures previously described in this paper differentially condition reinforcers may lead to the development of new reinforcer conditioning technologies as well as hold important implications for the concept of motivating operations.

**Purpose of the Study**

The purpose of this study was to replicate previous research on within-trial contrast and state-dependent valuation by examining changes in preference for stimuli that occur subsequent to differentially preferred events. In addition, this study extended previous research by (a) examining preference changes for initial links, (b) assessing
preference for initial, middle, and terminal links both before and after training, and (c) assessing whether terminal links were differentially conditioned as reinforcers.
Chapter 3: Study Method

Participants and Setting

Participants were recruited from Haugland Learning Center (HLC). HLC is a private school for children with developmental disabilities—primarily autism. As a requirement of participation in this study, students were required to (a) possess basic computing skills (e.g., be able to use a computer mouse, type numbers using a keypad, attend to a computer screen, etc.), (b) be able to independently complete math problems of difficulty ranging from single digit addition to double digit multiplication, and (c) be identified by the school as in need of some additional math practice. A recruitment letter was sent to the parents of students who met these criteria (see Appendix A). Once parental consent was obtained (see Appendix B), the participants were individually approached, the procedures of the study were explained, and verbal assent (see Appendix C) was obtained from each student.

Three students met the above requirements and were included as participants in this study. All students were Caucasian boys. At the time of the study, Heinrich was 11-years-old and had a diagnosis of Asperger syndrome, attention deficit hyperactivity disorder (ADHD), and obsessive-compulsive disorder. He was in the 6th grade. Jules and Bob were both 13-years-old. Jules was in the 6th grade and had a diagnosis of autism.
Bob was in the 7th grade and had a diagnosis of ADHD, oppositional defiant disorder, and a language processing disorder.

All study procedures were carried out in a 5’ x 8’ room equipped with a table, two chairs, a pencil and paper, and a laptop computer with a mouse and an external numeric keypad. Participants did not have any experience with this room prior to the beginning of the study.

**Equipment and Materials**

**Computer program.** All preference assessments, reinforcer assessments, and training trials were conducted via a computer program presented on a laptop computer. The computer program was developed by the researcher using Microsoft® Visual Basic® 2010 Express. The computer program began with a participant data input screen that allowed the researcher to assign all relevant variables (e.g., session number, condition type, participant name, number of trials, math type, etc.). After the necessary information had been input by the researcher, the selected condition was begun and the researcher handed the mouse and numeric keypad to the participant. Once the program began, all subsequent responses to the computer program were made by the participant. Participants engaged with the computer program via the computer mouse and external numeric keypad.

**Data recording.** Participant responses to each condition were recorded by the computer program and written to a .txt file on the laptop computer. Each session was written to a different file, and files were assigned a name based on the specific participant, condition type, and session number. A file named, *Heinrich--MSWO Initial*
Assessment--1.txt, for example, would indicate that the information contained in the file was from participant Heinrich, and was collected during Session 1 of the MSWO Initial Assessment condition. Assigning files based on this specific information ensured that all data were grouped by participant and condition, and were ordered appropriately.

Within a data file, all information from the participant data input screen was recorded into a data file (See Appendix F for an example). In addition, participant responses to the computer program were recorded, as was information specific to the condition. For example, during the initial MSWO preference assessments (described below) each individual button click was recorded, as was the button’s location in relation to other buttons (i.e., left or right or location within an array). During the reinforcer assessment (described below), the number of times the participant clicked a specific button and the time at which the button was clicked was recorded. During the training conditions, the total length of the training condition and the number of math problems skipped was recorded.

**Accuracy of data recording.** One of the benefits of having a computer program record participant responding is a high degree of reliability in data recording (Johnston & Pennypacker, 2009). A computer can record responses without bias, and this recording is precise from trial to trial relative to human data recording. Although reliability is high, it is quite possible for a computer program to contain faulty code that could impact the accuracy of the recording (i.e., the extent to which the data output reflects what actually happened during the study). As all responding was recorded by the computer, it is important that the accuracy of the recording be examined.
The accuracy of the computer generated data was examined both at the start and close of the study. To assess accuracy at the start of the study, artificial data were created on a data sheet. This represents a true value against which the computer output may be compared. The programmer then responded to the program based on that artificial data, thus simulating the responding of a participant. The artificial data and the computer output were then compared. To assess accuracy at the close of the study, the programmer again interacted with the program but this time used participant generated data as a guide. The programmer engaged in the same responses as the participant and compared the new data output with the participant generated data that guided responding. The goal of both of these accuracy assessments was to compare a true value (the responses of the programmer which were determined a priori) with the computer generated values. If the predetermined responses match with the data output, this would indicate that the computer was correctly recording all responses, and indicate a high degree of accuracy. This type of accuracy assessment was conducted for all preference and reinforcer assessments, as well as the training condition.

**Preference stimuli.** Eight random shapes were created using Microsoft Paint®. This was done to ensure participants had no previous contact with initial or terminal link stimuli. These shapes were randomly grouped into two sets of four and divided into initial and terminal link shape sets (see Figure 3.1). The initial and terminal link stimulus sets were identical for each participant; however, the individual shapes used throughout training were identified via an array of preference assessments (described below) and were therefore specific to each participant.
Math program. The computer program contained a math program specifically designed for this study. This math program could present single and double digit addition or multiplication problems. Additionally, the number of math problems required for each session could be set prior to the start of the math program. The program automatically ended once the participant had completed the required number of math problems.

When the math program began, the participant was presented with a start button. Clicking on the start button randomly generated numbers to fill the top and bottom boxes (see Figure 3.2), and began an invisible timer that recorded the total duration spent solving math problems. After inputting an answer, the participant clicked the “Check
Answer” button. A correct answer displayed the word “CORRECT” and produced a “Next Problem” button that generated a new math problem. An incorrect answer displayed the words “TRY AGAIN” and erased the input answer. The participant could then reattempt the math problem. If the participant made three errors on the same math problem, a “SKIP PROBLEM” button appeared that allowed the participant to skip the math problem. Skipping a math problem did not add towards completion of the required number of math problems.

![Math program](image)

**Figure 3.2.** Math program. Display shows the “Next Problem” button after a correct response.

**Baseline Preference Assessments**

Prior to entering the training condition, each participant was exposed to a variety of preference assessments. These assessments were conducted to determine preference for the different initial and terminal link shapes and to identify preferences for middle links (i.e., different math types/amounts). Furthermore, as one goal of this study was to
identify whether terminal links differentially functioned as reinforcers, a reinforcer assessment was conducted. Both the preference and reinforcer assessments were conducted multiple times both before and after the training condition.

**Middle link preference assessment.** Differentially preferred math problems served as the middle links in this study. For Jules and Bob, preference was assessed for different amounts of effort (i.e., number of math problems) via a paired-stimulus preference assessment (Fisher et al., 1992). With this preference assessment, two items are presented simultaneously and the participant is directed to select one of the items. The items are then removed, rearranged, and re-presented. If the paired-stimulus assessment is conducted on more than two items, the previously selected item may be presented alongside a new item during the second presentation. If only two items are being assessed (as was this case in this study), both items are re-presented in a rearranged format to control for possible side preference.

To assess preference for high versus low effort (i.e., more versus fewer math problems), Jules and Bob were seated at the computer and told they were going to complete math problems. A screen appeared that allowed the participants to choose to complete either more or less math problems (see Figure 3.3). Two buttons were visible and the participant could initiate the math problems by selecting either button. Above each button were the words “more” and “less” to indicate the amount of work required. In addition, each button was labeled with the specific number of math problems required. Furthermore, the participants were vocally told the various amounts of effort. For example, a participant may be told, “if you select this button, you will need to do five
math problems. If you select this button, you will need to do two math problems. Please choose a button.” Upon clicking one button, the math program began and the participant was required to complete the specified number of math problems. At this point, the participant was again exposed to the paired-stimulus assessment but the locations of the buttons were shifted. The effort assigned to the “more” and “less” buttons remained the same within a session of preference assessments.

![Figure 3.3](image)

**Figure 3.3.** Paired-stimulus preference assessment. Selecting either button opened a new form that contained the number of math problems listed on the clicked button.

For Heinrich, the preference conditions were different than those for Jules and Bob. After repeated exposure to the preference assessment procedures described above, Heinrich did not appear particularly sensitive to different amounts of math effort (i.e., he did not consistently select high over low effort or vice versa). In an effort to identify clearly high and low preferred conditions, Heinrich was exposed to a paired-stimulus preference assessment that included different *types* of math problems (i.e., addition
versus multiplication). For Heinrich, the preference assessment screen looked similar to Figure 3.1; however one button might have been labeled “15 math problems; single digit addition” whereas the other button might have been labeled “15 math problems; single digit multiplication.” Selecting either button opened a new screen containing the math problems specified on the button. Aside from different preference conditions, the paired-stimulus assessment procedures for Heinrich were identical to those for Jules and Bob. Participants engaged in two to four paired-stimulus preference assessments per day until a clear preference for one type or amount of math problem was evident.

The same paired-stimulus preference assessment was run again for each participant at the close of the study. The purpose of this final preference assessment was to determine whether math preferences changed over the course of the study. During this final assessment, procedures and test conditions for each participant were identical to those described above.

**Initial and terminal link preference assessments.** Preferences for the stimuli used as the initial and terminal link shapes were assessed via a multiple stimulus without replacement (MSWO) preference assessment (Cooper et al., 2007; DeLeon & Iwata, 1996). MSWO is a procedure that assesses preference among different items by systematically presenting the items and allowing the participant to make a selection. Once an item as been selected, all items are removed, rearranged, and re-presented minus the previously selected item. The assumption of the procedure is that the participant will select items in order of preference (from highest to lowest preference). By conducting the MSWO assessment several times, it is therefore possible to develop a hierarchy of
preference. This specific type of preference assessment was selected because it is useful in determining a preference hierarchy when assessing multiple stimuli. In addition, it has been shown to produce results equivalent to a paired-stimulus preference assessment in less time (DeLeon & Iwata, 1996).

For the MSWO, participants were seated at the computer and four shapes were displayed in a horizontal fashion on the computer screen (see Figure 3.4). These shapes were either the initial or terminal link shapes. The participants were told to use the computer mouse to select the shape they most preferred. When a shape was selected, all four shapes momentarily disappeared. The shapes then reappeared in a rearranged fashion minus the previously selected shape. This process continued until the participant had selected all four shapes one time.

Figure 3.4. Multiple stimulus without replacement preference assessment of initial link stimuli. Clicking one button resulted in the removal, rearrangement, and re-presentation of all shapes minus the one previously selected.
In order to initially rank preference for each stimulus, a point weighting method (Ciccone, Graff, & Ahearn, 2005) was used to calculate preference. In this method, points are assigned based on the order in which each stimulus is selected. In a four stimulus MSWO, for example, the first stimulus selected would receive a score of four, the second selected stimulus would receive a score of three, and so on. After multiple exposures to the MSWO, the points awarded for each stimulus are totaled and a final preference score is generated for each stimulus. This method can more accurately identify stimuli that later function as reinforcers than the more commonly used percentage scoring system (Ciccone et al., 2005).

There were two alterations to this scoring procedure. First, the scores assigned changed based on the number of stimuli being compared. For example, when comparing all four initial link stimuli to determine which shapes to use during training, the maximum score possible was four. This is because four stimuli were being compared. Once two stimuli had been selected for use in training, it was only necessary to compare these two stimuli. Therefore, the maximum score when comparing these stimuli was two. This new score reflects the order in which one training stimulus was selected in relation to the other.

Although the MSWO assessments always included four stimuli in the array, assigning a score to all four stimuli could artificially inflate or deflate the scores for the two stimuli being compared. Therefore, when comparing preference changes across baseline and posttraining conditions, the point weighting method was applied only to the stimuli used in training. The MSWO assessment in this case could be seen as
constituting two training stimuli (the two initial or terminal link stimuli) as well as two additional stimuli that functioned as distractors. Points were allotted based on when one training stimulus was selected in relation to the other training stimulus, not in relation to the distractors. The first training shape selected received a score of two whereas the second training shape selected received a score of one.

The second alteration to the scoring procedure was that the final scores were averaged for ease of comparison. The total score generated for each stimulus was divided by the number of assessment trials which resulted in an average point score for each stimulus. This was done so that the scale would be 1–4 or 1–2 (depending on the number of stimuli being compared) for each participant which allows scores to be more easily compared across participants. The MSWO assessment was conducted for both the initial and terminal link stimuli until either a clear hierarchy of preference, or indifference (i.e., selected in a seemingly arbitrary manner), was evident.

**Terminal link reinforcer assessment.** Following the MSWO for the terminal link shapes, a concurrent schedule reinforcer assessment was conducted (Catania, 1963). In a concurrent schedule reinforcer assessment, two different responses are available and each is associated with a different consequence. By pitting the two contingencies of reinforcement against one another, it is possible to assess the reinforcing value of each consequent stimulus. The assumption is that if one of the two responses increases over the other, the stimulus that is contingent upon the more frequent response is a stronger reinforcer.
Participants were seated at the computer and presented a screen consisting of two buttons (see Figure 3.5). They were told that they could click either button as much or as little as they preferred, and that the program would end after one minute. When one button was clicked, both buttons disappeared for 2 s during which a pre-programmed event occurred (described below). After 2 s had elapsed, the two buttons reappeared and the participant could again click on either button. After 1 min the program independently terminated; it was thus possible to engage in a maximum of 30 button clicks per assessment. Participants engaged in between 2 and 4 concurrent schedule reinforcer assessments per day.

Three different reinforcer assessments were conducted prior to exposure to the training condition. These reinforcer assessments differed only in regards to the stimulus used as the consequent event for clicking a button. In the first reinforcer assessment, the consequent event was a blank screen that appeared when either button was clicked. This assessment helped determine a baseline preference for button clicking independent of a consequence, and exposed any potential side preferences. Once preference for button clicking in the absence of a consequence was established, participants were exposed to the second reinforcer assessment.
The second reinforcer assessment used the highest preferred (HP) and least preferred (LP) terminal link shapes (as determined during the terminal link MSWO) as consequent events. A click to one button produced the HP shape for 2 s whereas a click to the other button produced the LP shape for 2 s. Although the contingencies for the left and right buttons remained the same during an individual reinforcer assessment session, they randomly altered across sessions. The purpose of this assessment was to test the assumption that a stimulus identified as being highly preferred would also function as a more effective reinforcer.

The third reinforcer assessment used the terminal link shapes that were most equally preferred (as identified by the terminal link MSWO). As during the second reinforcer assessment, the appearance of these shapes was contingent upon a button click and the location shifted across sessions. Thus the main difference between the first and second reinforcer assessments was that the first assessed the stimuli most unequal in
preference whereas the second assessed stimuli most equal in preference. Furthermore, the results of the third reinforcer assessment constituted the baseline condition for each participant.

**Experimental Design**

A multiple baseline design across participants (Cooper et al., 2007) was used in this study. Participants entered into the training condition (described below) in a staggered fashion, starting with the first participant to demonstrate stable responding during the third concurrent schedule reinforcer assessment. Data were collected for the other two participants for several more sessions whereupon the second participant with a stable baseline entered the training condition. Finally, after several more sessions had elapsed, the third participant entered into training. By staggering each participant’s entry into the training condition, the effect of the training condition on each participant’s preference can be documented with confidence.

**Training**

The training condition presented each participant with two separate components of initial, middle, and terminal links in a sequential and uninterrupted fashion. That is, from the start to the end of a training session, only responses made by the participant were necessary to advance the program. There was no interaction between researcher and participant during a training session. Of the two components created for each participant, Component 1 used a low preference middle link (LP-M) and Component 2 used a high preference middle link (HP-M) as determined through the paired-stimulus preference assessment.
The initial links used in each component were the stimuli most equally preferred during the initial link MSWO assessment. One initial link stimulus was assigned to the HP-M and the other stimulus was assigned to the LP-M. Although these initial links were selected because they were the most equally preferred, if a slight preference existed for one initial link over the other, the more preferred link was assigned to the LP-M. As it was hypothesized that the LP-M would decrease preference for the initial link, it seemed prudent to attempt to demonstrate a change in a direction opposite of an already existing preference.

The terminal links used in each component were the two stimuli used in each participant’s baseline reinforcer assessment. When the reinforcer assessment showed these two stimuli to function approximately equally as reinforcers, the terminal links were randomly assigned to the HP-M and LP-M. When the reinforcer assessment showed a greater value for one terminal link over the other, the more preferred terminal link was assigned to the HP-M. The reasoning for this assignment is similar to that of the initial links—preference was hypothesized to increase for stimuli following the LP-M, so it seemed prudent to assign the less preferred stimulus to this condition. To do otherwise would serve to capitalize on an already established preference and possibly confound interpretation of the results.

Figure 3.6 depicts a hypothetical training sequence. At the start of a training session, the participant was presented a screen that displayed a specific initial link (depending on whether the component was HP-M or LP-M). In order to evoke an attending response, the participant was required to click the initial link three times before
the middle link would begin. Each click to the initial link resulted in the removal of the initial link and then re-presentation after 2 s. This was to further ensure the participant attended to the initial link. Once the initial link had been clicked three times, the middle link appeared. The participant engaged in the middle link for the specific amount or type of problems (depending on whether the component was HP-M or LP-M). Once the participant had completed the middle link, the terminal link was presented in a fashion identical to the initial link. The participant was required to click the terminal link three times whereupon the program would automatically terminate. After the program was terminated, a second training session began depending on the number of sessions already completed for that day. In order to decrease the likelihood that the terminal link would be associated with the onset of the initial link, a 1 min intertrial interval was inserted between the offset of the terminal link and the onset of a second training session.
On each day of training, two to four training sessions were conducted per participant. Whether the training condition was HP-M or LP-M randomly alternated across days; however, the training sessions remained the same within a day. Thus, if the participant began a day in the HP-M condition, all training sessions were HP-M conditions. This was to ensure that the second session on a given day was not influenced by exposure to the first. If a participant preferred less work, for example, it is feasible that this work option would be less preferred if it followed exposure to a more work option. In addition to holding training sessions constant within a day, the number of exposures to the Component 1 and Component 2 was equivalent to ensure all initial, middle, and terminal links were contacted the same number of times. Finally, each
participant was exposed to at least six training sessions per HP-M and LP-M condition before being re-exposed to the preference and reinforcer assessments.

**Posttraining Assessments**

Once a participant completed 12 training sessions (six with HP-M; six with LP-M) that participant was again exposed to two MSWO preference assessments (initial and terminal link stimuli) and the concurrent schedule reinforcer assessment. These assessments served as comparison to the baseline assessments to determine whether preference and/or reinforcing efficacy had changed as a result of training. All posttraining assessments were run identical to baseline assessments. In addition, the number of trials of MSWO preference assessment during the posttraining condition was equal to the number during baseline trials. The reinforcer assessment was administered for at least four sessions for each participant to determine a change in reinforcing value. After the posttraining reinforcer and MSWO assessments were conducted, the participant was exposed to a *second training program*, as well as additional preference and reinforcer assessments.

**Second training program.** In order to increase the likelihood that a preference and reinforcer conditioning effect would be found if one existed, the original training program was augmented in two important ways. First, a screen was inserted between the offset of the initial link and the onset of the middle link. This screen displayed text that indicated the number of problems and type of math work for the upcoming middle link. The purpose of this additional screen was to increase the likelihood that the initial links would come to function as discriminative stimuli. This was particularly important for
Jules and Bob. For both participants, the LP-M and HP-M differed only by the number of math problems required. Prior to the second training program, however, this number was not indicated anywhere in training. Thus, the participant could discriminate the number of problems required only by actually completing a set of problems. Although repeated exposure to both LP-M and HP-M could eventually result in discrimination, a screen displaying the information seemed likely to speed the conditioning of both initial links as discriminative stimuli. This issue was less likely for Heinrich. As the LP-M and HP-M for Heinrich represented different types of math problems, it would be possible for Heinrich to discriminate between the two conditions based on the presence of either a “+” or “-” sign.

The second change to the training program occurred between the offset of the middle link and the onset of the terminal link. In the initial training program, the offset of the middle link resulted in a 2 s delay to the terminal link. Anecdotally, participants’ behavior changed (e.g., leaning back in chair, looking around the room, etc.) with the onset of the 2 s delay. This indicated that it might have been the 2 s delay, rather than the terminal link stimulus, that functioned as a discriminative stimulus for middle link termination. In the second training program, this 2 s delay was removed to increase the probability that the terminal link would become a discriminative stimulus for the program’s termination. Upon making this change to the program, finishing the last math problem in the middle link led immediately to a screen displaying the terminal link.

Each participant was exposed to 12 additional training sessions (six with LP-M; six with HP-M) with the second training program before additional reinforcer and
preference assessments were conducted. After these 12 additional training sessions, training was interspersed with both reinforcer and preference assessments throughout the remainder of the study.

**Questionnaire.** Once all posttraining assessments were complete, each participant was given a brief, relatively open-ended questionnaire regarding their selection of the initial and terminal link shapes. The questionnaire (Appendix D) presented the initial and terminal link shapes on separate pages and participants were asked to order the shapes in descending preference (1=most preferred, 4=least preferred). The participants were then questioned as to why they ordered the shapes in this particular order. The purpose of this questionnaire was to determine whether the participants were aware of the intent behind shape placement in the training sessions, whether shape placement during training factored into their selection of shapes during the MSWO assessment, and whether their explanation of preference would relate to differential preference for the middle links.
Chapter 4: Study Results

Baseline Assessments

Middle link preference assessments.

Jules. The results of the middle link preference assessment for Jules are depicted in Figure 4.1. The results of this paired-stimulus preference assessment are presented cumulatively. Jules did not appear particularly sensitive to differences in the effort amount when the math type was single digit multiplication. When the math type was changed to double digit multiplication, however, Jules chose to engage in less work 75% of the time (6 of 8 sessions) and more work only 25% of the time (2 of 8 sessions). These results indicate that when math type is double digit multiplication, Jules prefers to engage in less rather than more work. Therefore, during the training condition, two double digit multiplication problems served as the high preference middle link (HP-M) and 10 double digit multiplication problems served as the low preference middle link (LP-M).
Figure 4.1. Paired-stimulus preference assessment results for Jules. Results are graphed cumulatively.

**Bob.** After eight paired-stimulus preference assessments, Bob demonstrated a very clear preference towards engaging in more rather than less math work (see Figure 4.2). When presented the option between engaging in 10 single digit math problems or two single digit math problems, Bob consistently selected 10 math problems. During the last pre-training preference assessment session, the amount of effort required in the more condition was doubled but Bob still chose to engage in more math work. As the results of the preference assessment indicate a preference towards more work, 10 single digit multiplication problems were used as the HP-M condition and two single digit multiplication problems were used as the LP-M condition.
Figure 4.2. Paired-stimulus preference assessment results for Bob. Results are graphed cumulatively.

**Heinrich.** The results of the paired-stimulus preference assessment for Heinrich are presented in Figure 4.3. When presented with the option of engaging in either single digit multiplication or single digit addition math problems, Heinrich significantly preferred the multiplication work. When the number of math problems required for single digit addition was increased to 30 math problems, Heinrich chose to exclusively engage in the multiplication option. As a result of this assessment, during training the HP-M condition was 15 single digit multiplication problems and the LP-M was 30 single digit addition problems.
Figure 4.3. Paired-stimulus preference assessment results for Heinrich. Results are graphed cumulatively.

**Initial and terminal link preference assessments.**

**Jules.** The results of the baseline initial and terminal link preference assessments for Jules are depicted in Table 4.1. Five MSWO preference assessments were run for the initial link shapes and six assessments were run for the terminal link shapes. Using the point weighting method (Ciccone et al., 2005), the highest score an individual shape could receive for during the initial link assessment would be 20 points (5 trials x 4 points per trial). This would indicate highest preference. The lowest score possible would be five points (5 trials x 1 point per trial) indicating negligible preference. As the terminal link assessment was run six times, the highest possible score would be 24 and the lowest possible score would be six.
Jules displayed only moderately differentiated preference for the various shapes in the initial link assessment. Shape 3 appeared to be the most preferred shape (scoring 15 points) and Shape 1 appeared to be the least preferred shape (scoring 10 points). Based on the results of this preference assessment, Shapes 4 and 2 (scoring 13 and 12 respectively) were used as the initial links during training as these shapes were most similar in preference. Shape 4 preceded the LP-M condition and Shape 2 preceded the HP-M condition.

The results of the baseline terminal link preference assessment depict a similar indifference towards the various shapes with the exception of Shape 5 (scoring only 9 points). This shape appeared to be the least preferred shape and is only three points higher than the lowest possible score. Based on the results of the baseline terminal link preference assessment, Shapes 8 and 5 (the two most differentially preferred shapes; 18 and 9 points respectively) were used in the second reinforcer assessment and Shapes 7 and 6 (the two most equally preferred shapes; 17 and 16 points respectively) were used in the third reinforcer assessment.

**Bob.** The results of the initial and terminal link preference assessments for Bob are depicted in Table 4.1. Six MSWO preference assessments were conducted for both the initial and terminal link shapes. As a result, the highest score for an individual shape would be 24 and the lowest score would be six.

Bob displayed relatively clear preference for the shapes in the initial link assessment. Shape 1 was the most preferred shape (scoring 24 points) and was the first shape selected across all MSWO assessment sessions. Shape 4 was the least preferred
shape (scoring 9 points). Shapes 3 and 2 (scoring 15 and 12 points respectively) were moderately preferred over Shape 4 but relatively equal in preference to one another. Based on the results of the baseline initial link assessment, Shapes 3 and 2 were selected as initial links in the training condition. Shape 3 preceded the LP-M condition and Shape 2 preceded the HP-M condition.

During the terminal link preference assessment, Bob displayed high preference for Shapes 5 and 8 (scoring 21 and 20 respectively), and low preference for Shapes 7 and 6 (scoring 8 and 11 points respectively). Shape 7 was the least preferred shape and scored only two points higher than the lowest possible score. As a result of the baseline terminal link assessment, Shapes 5 and 7 (the two most differentially preferred shapes) were used in the second reinforcer assessment. Shapes 5 and 8 were used in the third reinforcer as these were the two most equally preferred shapes.

_Heinrich_. Table 4.1 displays the results of the initial and terminal link MSWO preference assessments for Heinrich. Six MSWO preference assessments were conducted for both the initial and terminal link shapes. As a result, the highest score for an individual shape would be 24 and the lowest score would be six.

In the initial link assessment, Heinrich displayed a strong preference for Shape 3 (scoring 21 points, only three points less than the maximum possible). Shapes 2, 4, and 1 were moderately preferred (scoring 14, 12, and 11 respectively) with Shape 1 being the least preferred shape. Based on the results of this preference assessment, Shapes 4 and 1 were selected as initial links during training as they were the most equally preferred. Shape 4 preceded the LP-M condition and Shape 1 preceded the HP-M condition.
Heinrich displayed relatively clear preferences for each shape in the terminal link MSWO preference assessment. Shape 5 was highly preferred (scoring 22 points) and scored only two points lower than the maximum score possible. Shapes 7, 8, and 6 were relatively equally preferred (scoring 15, 13, and 10 respectively) with Shape 6 being the least preferred shape. Based on these results, Shapes 5 and 6 were used in the second reinforcer assessment and Shapes 7 and 8 were used in the third reinforcer assessment.
Table 4.1. Initial and Terminal Link baseline preference assessment results

<table>
<thead>
<tr>
<th>Jules</th>
<th>Initial Link Shapes</th>
<th>Point Weighting Score</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape 3</td>
<td>15</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Shape 4</td>
<td>13</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>Shape 2</td>
<td>12</td>
<td>2.4</td>
<td></td>
</tr>
<tr>
<td>Shape 1</td>
<td>10</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Bob</td>
<td>Shape 1</td>
<td>24</td>
<td>4</td>
</tr>
<tr>
<td>Shape 3</td>
<td>15</td>
<td>2.5</td>
<td></td>
</tr>
<tr>
<td>Shape 2</td>
<td>12</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Shape 4</td>
<td>9</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Heinrich</td>
<td>Shape 3</td>
<td>21</td>
<td>3.5</td>
</tr>
<tr>
<td>Shape 2</td>
<td>14</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Shape 4</td>
<td>12</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Shape 1</td>
<td>11</td>
<td>1.8</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Terminal Link Shapes</th>
<th>Jules</th>
<th>Point Weighting Score</th>
<th>Average Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape 8</td>
<td>18</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Shape 7</td>
<td>17</td>
<td>2.8</td>
<td></td>
</tr>
<tr>
<td>Shape 6</td>
<td>16</td>
<td>2.6</td>
<td></td>
</tr>
<tr>
<td>Shape 5</td>
<td>9</td>
<td>1.5</td>
<td></td>
</tr>
<tr>
<td>Bob</td>
<td>Shape 5</td>
<td>21</td>
<td>3.5</td>
</tr>
<tr>
<td>Shape 8</td>
<td>20</td>
<td>3.3</td>
<td></td>
</tr>
<tr>
<td>Shape 6</td>
<td>11</td>
<td>1.8</td>
<td></td>
</tr>
<tr>
<td>Shape 7</td>
<td>8</td>
<td>1.3</td>
<td></td>
</tr>
<tr>
<td>Heinrich</td>
<td>Shape 5</td>
<td>22</td>
<td>3.6</td>
</tr>
<tr>
<td>Shape 7</td>
<td>15</td>
<td>2.5</td>
<td></td>
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<tr>
<td>Shape 8</td>
<td>13</td>
<td>2.1</td>
<td></td>
</tr>
<tr>
<td>Shape 6</td>
<td>10</td>
<td>1.6</td>
<td></td>
</tr>
</tbody>
</table>
First and second reinforcer assessments. In the first reinforcer assessment, a click to either button resulted in an identical 2 s blank screen. As the consequences for either button click were identical, the first reinforcer assessment was designed to reveal any potential side preferences for button clicking. The second reinforcer assessment used the most and least preferred terminal links as consequences and was designed to evaluate the assumption that high preference was indicative of strong reinforcing value.

Jules. The results of the first and second reinforcer assessments for Jules are presented in Figure 4.4. The first reinforcer assessment was conducted for four sessions. During this assessment, Jules alternated clicking between the left and right buttons. He displayed no significant side preference although clicks to the right button were slightly more frequent than clicks to the left button (left button = 7.32 per min; right button = 8.6 per min).

The second reinforcer assessment was also conducted for four sessions. Initially, it appeared that the HP Shape (the highly preferred shape from the MSWO assessment) functioned as a more effective reinforcer. During the first two sessions, responding was more frequent to the button that produced the HP Shape. After the first two sessions, however, responding became approximately equal regardless of whether the consequence was the HP or LP Shape.

When the two sets of data are compared we find that the total number of responses were approximately equal between the first and second reinforcer assessment. During the first reinforcer assessment, Jules emitted an average of 16.5 total responses per minute. During the second reinforcer assessment, Jules emitted an average of 18
responses per minute. This would indicate that for Jules there was some reinforcing value in clicking buttons even when those clicks produced only a blank screen.

Furthermore, the addition of the HP and LP Shapes as consequences did not significantly increase the total number of clicks in a session. This would indicate that the HP and LP Shapes did not exert differential control over button clicking and did not add any value to button clicking in general.

Figure 4.4. First and second reinforcer assessments for Jules. In the first assessment, a click to either button produced an identical blank screen. The second assessment compared the most preferred (HP Shape) and least preferred (LP Shape) shapes from the terminal link MSWO assessment.

**Bob.** The results of Bob’s first and second reinforcer assessments are depicted in Figure 4.5. The first reinforcer assessment was conducted for seven sessions. During the
first three sessions it appeared as though Bob preferred clicking the left button. As the assessment continued, however, Bob began to equally distribute his responding to each button with the exception of the last session. During the last session, Bob allocated more responses to the right button. Overall, the results of Bob’s first reinforcer assessment indicate that he did not significantly prefer one button location over the other.

The second reinforcer assessment was conducted for four sessions. The results of the second reinforcer assessment are difficult to interpret. On one hand, the overall results indicate that the LP Shape functioned as well or slightly more effectively as a reinforcer than the HP Shape. Overall, Bob emitted an average of 8.5 responses per minute (34 total responses) when the response produced the HP Shape. When the response produced the LP Shape, however, Bob emitted an average of 12 responses per minute (48 total responses).

When this higher overall responding to the LP Shape is contrasted with the pattern of both LP and HP Shape data paths, however, a different interpretation is possible. From session to session there is a large amount of variability, and response allocation oscillates consistently between the LP and HP Shape. This would indicate that the LP Shape did not function consistently more effectively as a reinforcer. Overall, the safest interpretation of the second reinforcer assessment data is that neither the LP nor HP Shape was significantly more effective as a reinforcer, although the LP Shape may have been slightly more effective.
Figure 4.5. First and second reinforcer assessments for Bob. In the first assessment, a click to either button produced an identical blank screen. The second assessment compared the most preferred (HP Shape) and least preferred (LP Shape) shapes from the terminal link MSWO assessment.

**Heinrich.** The results of the first and second reinforcer assessment for Heinrich are presented in Figure 4.6. The first reinforcer assessment was conducted for six sessions. During this assessment, Heinrich allocated responding significantly towards the right button. Furthermore, there was an increasing trend in responding to the right button as the sessions continued. On the last two sessions, Heinrich never responded to the left button. No physical aspects of the program were altered as a result of this finding. Throughout the remainder of the program, however, significant attention was given towards ensuring that shapes appeared equally on either side of the screen and alternated
in a random fashion across sessions. This helped ensure that any patterns in the data reflected real patterns in responding and were not artifacts of side preference.

The second reinforcer assessment was conducted for four sessions. During this assessment, the LP Shape functioned as a more powerful reinforcer than the HP Shape. When the consequence was the LP Shape, Heinrich responded an average of 13 times per min. When the consequence was the HP Shape, however, Heinrich responded at a rate of 5.25 per min. Furthermore, the LP Shape resulted in more total responses than the HP Shape across every session of the assessment. As the LP Shape appeared after a click to the left button on two sessions, these findings are not a result of side preference.

Figure 4.6. First and second reinforcer assessments for Heinrich. In the first assessment, a click to either button produced an identical blank screen. The second assessment compared the most preferred (HP Shape) and least preferred (LP Shape) shapes from the terminal link MSWO assessment.
Posttraining Assessments

After 12 training sessions, each participant was again exposed to the initial and terminal link MSWO preference assessments, the middle link paired-stimulus preference assessment, and the reinforcer assessment. The results of these posttraining assessments are described below.

Stability of middle link preferences. At the close of the study, two paired-stimulus preference assessments were again conducted for each participant. The purpose of these final assessments was to determine whether preferences for the middle links had changed over the course of the study. The number and type of problem assessed were identical to those used for each participant throughout training. The results of this final paired-stimulus assessment are depicted for each participant in the final phase of Figures 4.1, 4.2, and 4.3. Preferences remained unchanged for each participant across the course of the study which indicates a high degree of stability in middle link preferences.

Initial and terminal link preference assessments.

Jules. The results of the initial and terminal link preference assessments for Jules are presented in Figure 4.7. The maximum possible score for these preference assessments is two and the minimum possible score is one (recall that only two shapes are now compared). A score of zero is not possible. During baseline in the initial link preference assessment, a higher preference was exhibited for Shape 4. Out of a maximum possible score of two, Shape 2 averaged 1.4 points and Shape 4 averaged 1.6 points. During training, Shape 2 led into the high preferred middle link (HP-M; two
double digit multiplication problems) and Shape 4 led into the low preferred middle link (LP-M; 10 double digit multiplication problems). After repeated exposure to training, preference for the two initial links was again assessed. Consistent with anticipated outcomes, preference for the two shapes switched—Shape 2 increased in preference (from an average of 1.4 to 1.6) and Shape 4 decreased in preference (from an average of 1.6 to 1.4). This indicates that the HP-M and LP-M exerted a conditioning effect on the two initial links. Furthermore, the data indicate that, as would be expected, the shape associated with the more preferred task became more preferred, and the opposite effect was seen for the shape associated with the less preferred task.

During baseline in the terminal link preference assessment, preference for Shapes 6 and 7 was equal at an average of 1.5 points. During training, Shape 6 was associated with the termination of the HP-M, and Shape 7 was associated with the termination of the LP-M. During the posttraining assessment, a decrease in preference was observed for Shape 6 (from an average of 1.5 to 1.4) whereas an increase in preference was observed for Shape 7 (from an average of 1.5 to 1.6). Preference for both Shape 6 and 7 remained unaltered after exposure to the second training program. This change in preference is consistent with the predictions of within-trial contrast and indicates that preference was increased for the stimulus that followed the less preferred activity.
Figure 4.7. Preference changes for initial and terminal links across baseline and training conditions for Jules. *Before* HP-M or LP-M indicates the shape appeared before the high preference (HP-M) or low preference (LP-M) middle link. *After* HP-M or LP-M indicates the shape appeared after the specified middle link.

*Bob.* The results of the initial and terminal link preference assessments for Bob are depicted in Figure 4.8. During the initial link baseline, Shape 3 appeared to be more preferred than Shape 2—Shape 3 averaged 1.7 points during baseline whereas Shape 2 averaged 1.3 points. Shape 3 was then associated with the introduction of the LP-M (two single digit multiplication problems), Shape 2 was associated with the introduction of the HP-M (10 single digit multiplication problems), and Bob was exposed to the training condition. During the posttraining assessment for the initial link, a decrease in preference was noted for Shape 3 (from an average of 1.7 to 1.3) and a corresponding increase in preference was noted for Shape 2 (from an average of 1.3 to 1.7). As with Jules, the
results of the initial link preference assessments for Bob indicate that the HP-M and LP-M conditions exerted a conditioning effect on their associated initial link shapes. Furthermore, the changes in shape preferences were in expected directions—preference increased for the shape associated with the introduction of the HP-M and decreased for the shape associated with the introduction of the LP-M.

During the terminal link baseline preference assessment, Shapes 5 and 8 were equally preferred and averaged 1.5 points each. Shapes 5 and 8 were then associated with the termination of the HP-M and LP-M conditions respectively. When preference for the two shapes was assessed after exposure to the initial training condition, no change in preference was observed—both shapes continued to average 1.5 points each.

After exposure to the second training program, preference for Shape 5 increased (from 1.5 to 1.8) and preference for Shape 8 decreased (from 1.5 to 1.2). Thus, the changes in preference for Bob were not as predicted by within-trial contrast—an increase in preference was noted for the stimulus that followed the more preferred activity and a decrease in preference was noted for the stimulus that followed the less preferred activity.
Figure 4.8. Preference changes for initial and terminal links across baseline and training conditions for Bob. *Before* HP-M or LP-M indicates the shape appeared before the high preference (HP-M) or low preference (LP-M) middle link. *After* HP-M or LP-M indicates the shape appeared after the specified middle link.

**Heinrich.** The results of the initial and terminal link preference assessments for Heinrich are presented in Figure 4.9. During the baseline initial link preference assessment, Shape 2 averaged 1.6 points and Shape 1 averaged 1.3 points, indicating a higher preference for Shape 2. Shape 2 and 1 were then associated with the introduction of the LP-M condition (30 single digit addition problems) and HP-M condition (15 single digit multiplication problems) respectively and Heinrich was exposed to a series of training trials. During the posttraining initial link preference assessment, changes in preferences for the two shapes were consistent with expectations. The preference score
for Shape 2 (associated with the LP-M condition introduction) decreased from 1.6 to 1 and the preference score for Shape 1 (associated with the HP-M condition introduction) increased from 1.3 to 2. Thus, as with Jules and Bob, it appears that the HP-M and LP-M conditions exerted the expected conditioning effect on the two initial link shapes. Preference increase significantly for the shape associated with the introduction of the HP-M condition and decreased for the shape associated with the introduction of the LP-M condition.

During the baseline terminal link preference assessment, a slightly greater preference appeared to exist for Shape 7 (averaging 1.7 points) than for Shape 8 (averaging 1.3 points). During training, Shape 7 was associated with the termination of the HP-M condition and Shape 8 was associated with the termination of the LP-M condition. During the posttraining terminal link preference assessment, a slight decrease in preference was observed for Shape 8 (from 1.3 to 1.2) and a slight increase in preference was seen for Shape 7 (from 1.7 to 1.8).

Preference for Shape 7 and Shape 8 remained unchanged after exposure to the second training program. The results of the terminal link preference assessment are inconsistent with the predictions of within-trial contrast. After training, preference increased for the stimulus associated with the termination of the more preferred activity and decreased for the stimulus associated with the termination of the less preferred activity.
Figure 4.9. Preference changes for initial and terminal links across baseline and training conditions for Heinrich. *Before* HP-M or LP-M indicates the shape appeared before the high preference (HP-M) or low preference (LP-M) middle link. *After* HP-M or LP-M indicates the shape appeared after the specified middle link.

**Questionnaire results.** At the end of the study, each participant completed a brief questionnaire (Appendix D) that asked the participant to rank the initial and terminal link stimuli in a descending order of preference. In addition, the participants were asked to explain why they preferred various shapes over other shapes.

**Initial link shapes.** When asked to order the initial link shapes in descending preference, the responses of Jules, Bob, and Heinrich matched their responses to the initial link MSWO preference assessment. That is, on the questionnaire, all participants selected the stimulus that preceded the HP-M in training *before* selecting the stimulus that had preceded the LP-M. Jules ordered Shape 2 before Shape 4, Bob ordered Shape 2
before Shape 3, and Heinrich ordered Shape 1 before Shape 2. When questioned as the reason certain shapes were preferred more than others, Jules and Heinrich both described an item the shape looked like as opposed to describing a strategy for selecting the shape. For example, Heinrich said Shape 1 “looks like a bunny slipper,” Shape 2 “looks like a piggy,” Shape 3 “looks like Elvis,” and Shape 4 “looks like a vulture.” Bob specified that he preferred shapes that were more complicated or difficult to draw, and indicated that he arranged the shapes in a descending order of complexity. None of the participants indicated that the arrangement of the stimuli during training had any impact on the order in which they ranked the initial link stimuli.

**Terminal link shapes.** When asked to order the terminal link shapes, Jules arranged the shapes in a pattern similar to that seen during the terminal link MSWO preference assessment—he indicated that he preferred Shape 7 (the shape following the LP-M) over Shape 6. This a preference order predicted by within-trial contrast. When asked why he arranged the shapes in this order, Jules stated “some catch my interest and look like they are from Star Wars.” Similar to his responses to the initial link questionnaire, he then went on to describe specific items each shape resembled.

Bob arranged the shapes differently than he had during the terminal link MSWO assessment. During the MSWO assessments, Bob consistently ordered Shape 8 (the shape following the LP-M) after Shape 5, indicating less preference for Shape 8. Of the six MSWO trials conducted after training with the second training program, Bob deviated from this order only one time. The last four terminal link MSWO trials consistently placed Shape 5 at a higher preference. On the questionnaire, however, Bob ordered
Shape 8 before Shape 5 indicating he preferred the shape that followed the less preferred middle link over the shape that followed the more preferred middle link. This is in accordance with the predictions of within-trial contrast. When asked why he arranged the shapes in this particular order, Bob again indicated he preferred more complicated shapes and ordered the shapes in terms of decreasing complexity.

Heinrich arranged the shapes in a preference order similar to that indicated by the terminal link MSWO preference assessment. On the questionnaire, Heinrich indicated a higher preference for Shape 7 (the shape that followed the more preferred middle link during training) than for Shape 8. When asked why he arranged the shapes in this particular order, Heinrich again simply described an item each shape resembled. None of the participants stated that the training condition impacted preference for the various terminal link stimuli.

**Summary of changes in initial and terminal link preference.** In general, it appears that the procedures of the study produced two different preference conditioning effects. Associating the initial link stimuli with the onset of differentially preferred middle links was sufficient to change initial link stimulus preferences for all participants. For Jules, Bob, and Heinrich, the stimulus that preceded the more preferred middle link increased in preference whereas the stimulus that preceded the less preferred middle link decreased in preference. Furthermore, this preference change was in a direction opposite of a previously established preference. That is, for each participant, preference changed so that the stimulus that was less preferred during baseline became the more preferred stimulus in posttraining.
The effect of differentially preferred middle links on preference for subsequent stimuli is less straightforward. The within-trial contrast phenomenon would predict that preference would increase for stimuli following less preferred events and decrease for stimuli following more preferred events. Based on the terminal link MSWO preference assessments, this effect was only demonstrated for Jules; preference changes were in a direction opposite of within-trial contrast predictions for Bob and Heinrich. This finding, however, is somewhat complicated by responses to the questionnaire that indicate a within-trial contrast effect for both Jules and Bob.

**Third reinforcer assessment.** The results of the third reinforcer assessment for Jules, Bob, and Heinrich are depicted in Figure 4.10. Overall, it does not appear as though the reinforcing value of any of the terminal link shapes was systematically altered as a function of either the first or second training conditions. For Jules, responding to either button of the concurrent schedule reinforcer assessment was approximately equal across baseline, posttraining, and the second training program. Neither shape appeared to function more effectively as a reinforcer.

For Bob, Shape 5 initially appeared to be a more effective reinforcer and responding gradually increased over the first three sessions. After the first three sessions, however, responding briefly shifted towards the button that produced Shape 8 before response allocation began to oscillate between both buttons. This variability in responding gradually decreased over the following sessions and responding was eventually distributed equally across both buttons. This decreasing variability in
responding was observed across baseline as well as the first and second training conditions.

For Heinrich, Shape 7 appeared to be a more potent reinforcer. During baseline, responding was primarily directed towards the button that produced Shape 7 with the exception of sessions 1, 7, 8, and 9. During these sessions, responding was directed more towards the button that produced Shape 8. Responding again shifted towards Shape 7 at the end of baseline, and remained high across both the first and second training conditions.
Figure 4.10. Results of the third concurrent schedule reinforcer assessments for Jules, Bob, and Heinrich. After - HP-M indicates the shape followed the high preference middle link whereas After - LP-M indicates the shape followed the low preference middle link.

Accuracy of computer data recording. The accuracy of the computer data output was assessed at the start and close of the study. Accuracy was assessed by creating a true value (i.e., determining what the output should), engaging with the computer program so as to recreate the data, and then comparing the true value with the
computer data output. This accuracy assessment was conducted for the paired-stimulus assessment, both initial and terminal link MSWO assessments, the concurrent schedule assessment, and the training conditions. Accuracy was determined to be 100% across all assessments and the training condition, thus indicating that the computer generated data output (the primary data for this study) accurately reflects participant responding.
Chapter 5: Study Discussion and Conclusion

The Relation Between Preference and Reinforcing Value

Research on the within-trial contrast effect has demonstrated that stimuli preferences may increase when those stimuli follow less preferred activities. This effect was evident for one participant in this study. In addition to attempting to replicate the within-trial contrast effect, one purpose of this study was to determine whether an increase in preference would also lead to an increase in reinforcer potency. Overall, this did not appear to be the case. The results of the second reinforcer assessment, however, indicate that this may not be a failing of within-trial contrast. Instead, the fact that changes in preference did not lead to changes in reinforcing value may simply reflect a reality of the relation between preference and reinforcing efficacy.

In the second reinforcer assessment, the reinforcing value of the most and least preferred terminal link stimuli (as determined through the MSWO assessment) was evaluated. The results of this evaluation provide further evidence that high preference for a stimulus does not necessarily indicate a strong reinforcing value. For Jules (Figure 4.4), the baseline MSWO assessment indicated highly differentiated preferences between the HP Shape and the LP Shape. Out of four possible points, the HP Shape scored an average of three and the LP Shape scored an average of 1.5. Based on this assessment, one would expect responding in the second reinforcer assessment to be allocated...
primarily towards the button that produced the HP Shape. At the beginning of the reinforcer assessment, this appeared to be the case—the HP Shape was a more potent reinforcer and responding was distributed accordingly. As the assessment continued, however, responding became approximately equally distributed between the two buttons, indicating that the HP and LP Shapes functioned equally as reinforcers.

The results for Bob and Heinrich demonstrate a similar discrepancy between the MSWO preference assessments and the reinforcer assessments. For both participants, the MSWO assessment revealed a strong difference in preference between the HP and LP Shape. For Bob the HP and LP Shapes averaged 3.5 and 1.3 points respectively, and for Heinrich the HP and LP Shapes averaged 3.6 and 1.6 points respectively. Based on these findings, responding should have been allocated primarily to the button that produced the HP Shape. For both Bob and Heinrich, this proved not to be the case. Bob displayed a high degree of variability in responding and oscillated between responding to the HP Shape and the LP Shape (Figure 4.5). A molar analysis of Bob’s responding reveals that overall Bob emitted more responses to the button that produced the LP Shape. For Heinrich, responding was significantly higher to the button associated with the LP Shape (Figure 4.6). In every session, responding was allocated more towards the LP Shape button. Thus, the second reinforcer assessment demonstrates that a high preference stimulus may not actually function as a more effective reinforcer.

**Possible explanations for findings.** It is unclear why such a discrepancy exists between the results of the MSWO assessment and the results of the second reinforcer assessment. Previous research has demonstrated that, although more preferred stimuli
typically function as more effective reinforcers than less preferred stimuli, there is some breakdown in this correlation with less effective reinforcers. Lee, Yu, Martin, and Martin (2010), for example, evaluated the reinforcing efficacy of a variety of stimuli and developed a hierarchy of reinforcer potency. They then conducted a preference assessment on these same stimuli and compared the results of the preference assessment with the results of the reinforcer assessment. In general, they found that as reinforcer efficacy decreased, so did preference. They also found, however, that the stimuli that were the least effective reinforcers were occasionally ranked as moderately preferred stimuli. In fact, some of the least effective reinforcers were ranked as more preferred than other, more effective reinforcers.

It is possible that the same discordance between preference and reinforcing efficacy was present in this study. The terminal link stimuli used in this study were random shapes, drawn by the researcher, with which the participants had no previous contact. It is reasonable to assume, therefore, that the shapes were only minimally reinforcing or of neutral value. This being the case, the Lee et al. (2010) study would suggest that the results of a preference assessment may not be highly positively correlated with the results of the reinforcer assessment.

A second possibility concerns the nature of the MSWO assessment itself. The assumption behind an MSWO assessment is that a participant will select stimuli in order of decreasing preference. The most preferred stimulus will be selected first and the least preferred stimulus will be selected last. This assumption seems justifiable when the stimuli are somehow consumable (e.g., edible items) or can be physically engaged with
(e.g., toys). When assessing preference with edible items, for example, it seems reasonable to assume that a more preferred food item will be consumed first and the least preferred food item will be consumed last or not at all. The stimuli used in this study, however, were shapes and therefore could be engaged with only visually. Assuming that a participant would want to prolong exposure to a more preferred visual stimulus, more preferred items may actually be selected after less preferred items. Responding in this manner would maximize contact with the more preferred items and minimize contact with the less preferred items. This would then reverse the results of the MSWO assessment, in which case the results of the second reinforcer assessments would be somewhat expected.

Although this is a possibility, it seems unlikely for two reasons. First, the participants were explicitly instructed to select items in order of decreasing preference, and this instruction was provided prior to every MSWO assessment. All participants were high functioning and able to follow directions so it is reasonable to assume they responded according to directions. Second, the responses of the participants to the questionnaire indicated that items were selected in order of descending preference. When asked to describe why items had been arranged in a specific order, each participant indicated that the item selected first had been more preferred than the item selected last.

Although it is unclear why the participants’ preference results did not match with the results of the reinforcer assessment, this finding highlights the need to determine whether the within-trial contrast effect conditions stimuli as reinforcers. Previous research on the within-trial contrast effect has demonstrated that preference for stimuli
may change as a result of exposure to less preferred events. From an applied standpoint, however, identifying preference is important because it yields information regarding potential reinforcers. As the findings of the second reinforcer assessment demonstrate, increasing preference for stimuli does not necessarily mean that those stimuli will also function more effectively as reinforcers. This finding underscores the need for separate reinforcer and preference assessments when examining the within-trial contrast effect.

**Changes in Reinforcing Efficacy**

Similar to the findings of the second reinforcer assessment, it appears that the changes in stimulus preferences due to training did not consistently correlate with changes in the reinforcing efficacy of those stimuli. For Jules and Bob, preferences for terminal link stimuli were equal at baseline and changed after exposure to training. This preference change, however, did not result in a change in reinforcer efficacy; by the end of the study, both terminal link stimuli functioned approximately equally as reinforcers. For Heinrich, preference at the start of the study was high for one stimulus and the reinforcer assessment indicated this shape to also be a more potent reinforcer. By the end of the study, preference and reinforcer efficacy for this shape had increased.

These results are unsurprising when viewed in light of the findings of the second reinforcer assessments—more preferred stimuli did not necessarily indicate a more potent reinforcers. In terms of answering the initial question as to whether within-trial contrast could change preference as well as reinforcer potency, only Jules’ data are able to provide some insight. The initial finding regarding this question is that a change in
preference due to within-trial contrast is not sufficient to exert a change in reinforcing efficacy.

**Changes in Preference for Initial and Terminal Link Stimuli**

**Initial link preference changes.** The finding that preferences for the initial link stimuli changed as a function of the type of middle link event each stimulus preceded is anticipated, but valuable nonetheless. When a stimulus consistently precedes a specific event, that stimulus may become a discriminative stimulus for either reinforcement or punishment. When a stimulus precedes a preferred event, the stimulus signals the availability of upcoming reinforcement and the stimulus itself may become preferred. Conversely, when a stimulus precedes a non-preferred event, the stimulus signals an upcoming worsening of events and may become non-preferred. The procedures of this study, as they pertain to the presentation of the initial link, were designed to effect this change in preference for the initial link. To that end, the procedures appeared to be effective.

Although the findings regarding initial link preference changes are common, they are potentially important for this study. The finding that initial link preferences changed in the expected directions for all participants provides evidence for the validity of the middle link preference assessment outcomes. The middle link preference assessments were designed to identify preferences for different types and amounts of math work. It is always possible, however, that the outcomes of the paired-stimulus assessments do not reflect true preferences for math work. If this were the case, a negative finding in regards to within-trial contrast would be difficult to interpret—if contrast was not demonstrated,
it could always be argued that preference for the middle link events was not accurately identified. Finding that the middle links did have an expected conditioning effect on the initial links diminishes this argument. The changes in initial link preference increase confidence that the two middle links were at least differentially preferred enough to change preferences for the stimuli that preceded them.

**Terminal link preference changes.** The within-trial contrast effect was demonstrated only for Jules. For Bob and Heinrich, the effects of training were to increase preference for the stimuli that followed more preferred middle links, rather than less preferred middle links. Using the preference assessment results from the questionnaire, a contrast effect was noted for Bob; however, this result contradicts the findings of the somewhat more rigorous MSWO assessment. It is difficult, therefore, to draw a firm conclusion one way or the other regarding Bob. The safest overall conclusion is that a contrast effect was demonstrated for Jules, was tenuous at best for Bob, and was non-existent for Heinrich.

**Possible explanations for findings.** There are several possible explanations for the findings regarding terminal link preference changes. The most obvious explanation is that the two middle link events were not differentially preferred enough to exert a conditioning effect on the terminal link stimuli. All current models of the within-trial contrast effect require the two middle links to be differentially preferred. Findings with other contrast effects (e.g., incentive, behavioral) have shown that as the difference between the two conditions increases, the contrast effect is increased (e.g., Flaherty, 1996). It therefore seems reasonable to assume that the same finding would hold true for
within-trial contrast—as the difference in middle link preferences increases, so does the likelihood of contrast.

The middle link preference assessments demonstrated clear preference differences between the two middle links. It is possible, however, that both middle links were somewhat preferred, with one middle link only slightly more preferred than the other. For example, the results of the middle link preference assessment for Bob indicate that he preferred to engage in more work rather than less work. When he was given the option between 2 and 10 math problems, he consistently chose the greater effort option. Although Bob preferred more work, this should not be interpreted as meaning that less work was aversive. If, for example, Bob were offered an option between 10 and 20 math problems and selected the 20 math problems option, we could not then conclude that the 10 math problems option was now aversive. Rather, one option is simply preferred more than the other option—the ultimate difference in aversiveness between these two options is unknown. Although there were differences in middle link preferences for each participant, if this difference was only slight it is possible that a contrast effect would not be demonstrated.

This explanation is contradicted to some extent by the finding that a preference conditioning effect was consistently demonstrated with the initial links. Thus the differentially preferred middle links did condition stimulus preferences for the stimuli that preceded them. The middle links did not, however, consistently condition preference for the stimuli that followed them. Because a conditioning effect was found for the initial link stimuli, we can confidently conclude that the middle links were able to exert at least
some conditioning effect. However, because a conditioning effect was not exerted on the terminal link stimuli, we may conclude that the within-trial contrast effect is somehow different from, or weaker than, the more common conditioning of the initial link stimuli. It is possible that stimuli that precede an event are more easily conditioned than stimuli that occur after an event.

A second explanation for the inconsistent findings regarding within-trial contrast is that events occurring after the presentation of the terminal link exerted a conditioning effect. It is possible, for example, that the conditioning effect of the middle link was counteracted by a possible conditioning effect of events during the intertrial interval. Recall that for each participant the presentation of the terminal link signaled the end of the middle link and also the onset of the 1 min intertrial interval. During this interval, the researcher entered the student information into the computer program and the participant and researcher conversed with one another. Assuming that this conversation was a preferred event (which it anecdotally appeared to be), this represents a 1 min preferred event following engagement with the terminal link. As this event was held constant for across all training trials, this does not appear to be problematic at first glance.

Upon closer inspection, however, the length of time between the presentations of intertrial intervals does appear to differ. For a given participant, the length of time it took to complete the HP-M differed from the length of time it took to complete the LP-M. For example, for Heinrich it took an average of 1 min to complete the 15 multiplication problems and just over 2 min to complete the 30 addition problems. This would mean that the length of time between the researcher-participant conversations (during the
intertrial interval) was less during training with the HP-M than during training with the LP-M. It is possible, then, that the terminal link following the HP-M increased in preference because it signaled the onset of the conversation and also a shorter amount of time to the next conversation.

This explanation, however, is contradicted by the preference change results found for Jules and Bob. For Jules, the HP-M (two multiplication problems) took approximately 56 s to complete and the LP-M (10 multiplication problems) took approximately 4.2 min to complete. As a within-trial contrast effect was noted for Jules, this means that preference increased for the terminal link associated with a much longer interval between conversations. For Bob the HP-M (10 multiplication problems) took approximately 1.25 min to complete whereas the LP-M (2 multiplication problems) took approximately 12 s to complete. As a within-trial contrast effect was not noted for Bob, this means that preference increased for the terminal link associated with the HP-M, and therefore associated with the longer interval between conversations. Thus, although a possible explanation, differences in the delays to the intertrial intervals seems an unlikely explanation for the inconsistent findings of within-trial contrast.

A third possible explanation for the inconsistent findings is that preferences for these stimuli may have been affected by repeated exposure to the various preference and reinforcer assessments. The mere exposure effect (see Bornstein, 1989) is a well documented phenomenon wherein preference for stimuli increases simply as a result of repeated exposure to those stimuli. Although the effect is not as robust with picture shapes (such as those used as terminal link stimuli), the effect has been documented
previously. Furthermore, Bornstein conducted a meta-analysis of studies conducted between 1968 and 1987, and found that, among other factors, preference increased when stimuli were more complex and when exposure to those stimuli was brief. These factors describe the reinforcer assessment to a large extent—stimuli were semi-complex shapes presented for 2 s following a button click. It is possible, therefore, that terminal link preferences were affected by exposure to the various preference assessments. Repeated exposure to the reinforcer assessments could have then functioned to solidify preference changes.

When analyzing the preference changes for terminal link stimuli after exposure to the first set of training trials (see posttraining phase in Figures 4.7, 4.8, and 4.9), Jules’ data demonstrate a clear contrast effect, Bob’s data demonstrate no change (although the questionnaire revealed positive contrast), and Heinrich’s data demonstrate a preference change opposite of that predicted by within-trial contrast. Viewed in light of the mere exposure effect, this pattern could be interpreted as reflective of the amount of time spent engaged in the reinforcer assessment. Because a multiple baseline across participants was employed as the experimental design, participants necessarily spent different amounts of time in the baseline condition. As reinforcer assessments were conducted throughout baseline, participants therefore also spent different amounts of time engaged in the reinforcer assessment (compare baseline lengths in Figure 4.10). Reinforcer assessments were conducted across 5 sessions for Jules, 8 sessions for Bob, and 11 sessions for Heinrich. Thus, the participant who spent the least amount of time engaged in the reinforcer assessment, and therefore received less exposure to the terminal link
stimuli, displayed a preference change consistent with within-trial contrast. The more
time participants spent engaged in baseline, the more likely they were to display
preference changes opposite those predicted by within-trial contrast during the first
posttraining assessments.

This possible explanation is further supported by the participants’ responses to the
questionnaire delivered at the close of the study. Participants were asked to order the
four terminal link shapes in descending preference, and were then asked why they liked
some shapes more than others. In general, there appeared to be a positive correlation
between the length of time spent in the reinforcer assessment and the amount of
information provided regarding preference. Jules, for example (who spent the least
amount of time in the reinforcer assessment), simply stated “some catch my interest and
look like they are from Star Wars.” Heinrich, on the other hand, who spent the most time
in the reinforcer assessment, described each shape individually and specified an item he
felt the shape resembled. The finding that description of the stimuli increased based on
time in the reinforcer assessment provides further evidence that greater exposure to the
various assessments influenced preference.

Finally, this provides a possible explanation for the different conditioning effects
noted for the initial and terminal link stimuli. During baseline, participants were
repeatedly exposed to the reinforcer assessment. This assessment, however, examined
only the terminal link stimuli; initial link stimuli were never examined in the reinforcer
assessment. Thus, exposure to the initial link stimuli was minimal and held constant
across participants whereas exposure to the terminal link was extensive and varied across
participants. Finding an anticipated conditioning effect for the initial link stimuli, but not for the terminal link stimuli, lends further support to the idea that repeated exposure to the reinforcer assessments altered stimulus preferences.

**Limitations and Directions for Future Research**

There are several limitations to this study, as well as additional avenues for future research. The first limitation is that repeated exposure to the preference and reinforcer assessments could have constituted an extraneous variable that influenced preference changes for the terminal link stimuli. Future research should attempt to limit and hold constant the number of exposures to the various assessments. One way researchers employing single-subject methodology could do this is by using a multiple probe design. In a multiple probe design, fewer assessments would need to be conducted during baseline. Furthermore, the number of assessments conducted per participant could be held constant by staggering the probes in such a way that the total number of probes is equal across participants.

A second limitation of this study is that terminal link preferences were unequal for Heinrich during the baseline condition. According to within-trial contrast and the organization of stimuli in this study, preference changes across the course of the study were anticipated in a direction opposite of baseline preferences. Therefore, preference differences during baseline do not constitute a procedural problem. However, until the within-trial contrast effect is more thoroughly researched, it seems unwise to work against already established preferences. This is especially true when preferences are highly differentiated, as was the case with Heinrich. In such a situation, a researcher
would need to not only demonstrate the within-trial contrast effect, but also demonstrate that the effect was strong enough to counteract established preferences. In this case, if a study resulted in a failure to replicate the contrast effect, it would be unclear whether this failure was due to abnormally high or low baseline preferences, or whether the effect did not exist for that participant. Future research should study the within-trial contrast by using terminal link stimuli that are equally preferred. To do this, a larger array of stimuli could be developed for use in a preference assessment; only those stimuli found to be equally preferred would be retained and used as terminal link stimuli.

A third limitation is that, as noted previously, it is possible that preferences for the middle link events were only slightly different. A paired-stimulus preference assessment does not necessarily provide information regarding the *extent* to which one stimulus is preferred over the other. If one stimulus is highly aversive, it will be selected second; if one stimulus is only slightly aversive, it will also be selected second. Therefore, the degree to which one stimulus is preferred over the other is not revealed in a paired-stimulus preference assessment. If, however, the two middle link events are only slightly differentially preferred, it is unlikely that a contrast effect would be demonstrated. Future research should examine within-trial contrast by first identifying middle link events that are clearly aversive or reinforcing. In addition, future research should determine whether the within-trial contrast effect is heightened by using middle links that are differentially aversive or reinforcing by different amounts. This could be accomplished by conducting a reinforcer assessment on multiple stimuli and determining which stimuli increase or suppress responding. A hierarchy of preferred and aversive stimuli could then be
developed. Achieving this, the effect of using different reinforcing or punishing middle link events could be systematically examined. In addition, a researcher could be confident that the two middle link events employed were differentially preferred and capable of exerting different conditioning effects.

Finally, it is particularly interesting that a conditioning effect was achieved on the initial link stimuli for all participants but on the terminal link stimuli for only one participant. Future research should examine these conditioning processes to determine if the within-trial contrast effect is merely a weak effect, or whether the two conditioning processes are fundamentally different. To date, the conditioning process of antecedent stimuli, such as the initial links, is well understood. The conditioning process of subsequent stimuli, as it relates to within-trial contrast, is less understood. As an organism interacts with the environment, some stimulus change must always follow another stimulus change event (preferred or not). It is feasible that a conditioning process continually occurs in this arrangement just as the antecedent conditioning process continually occurs. Future research into this area, and in particular into the process of conditioning stimuli on both ends of an event, will provide a more complete and accurate picture of how organisms interact with the world around them.
References


Appendix A: Recruitment Letter
Dear Parent/Guardian –

My name is James Meindl and I am a 3rd year Ph.D. candidate working with researcher Nancy Neef in the Special Education and Applied Behavior Analysis program at The Ohio State University. As a student in the program, I am interested in conducting research that will potentially provide beneficial results for school-age student both in and out of special education. You are receiving this letter because your child’s class is one that has been identified as potential candidates for my study.

From your child’s perspective, he/she will simply receive extra math assistance via a computer math program and will identify different shapes.

The information attached to this letter summarizes the purpose of my study as well as describes what the study would entail for your child. If you are interested in having your child participate in my study, please read the following information carefully as it will explain my study, describe your rights and your child’s rights (should you both agree to participation), and provide you with contact information should you have any questions.

If you decide to allow your child to participate in my study, please sign the parental permission form, place the form in the enclosed self-addressed stamped envelope and it will be mailed directly to me. This is to protect your privacy and the privacy of your child. Once I have received your permission, I will describe the study to your child to ensure he/she understands what participation will entail and I will then ask him/her for assent to participate.

If you have any questions regarding your child’s participation or any other aspect of this study, please don’t hesitate to contact me at 717.364.4857 or meindl.2@buckeyemail.osu.edu

Thank you,

James Meindl
Doctoral Candidate
The Ohio State University

Special Education • Sport & Exercise Education, Humanities, Management & Science
Counselor Education & School Psychology • Workforce Development & Education
Appendix B: Consent Form
The Ohio State University Parental Permission for Child’s Participation in Research

Dear Parent/Guardian –

My name is James Meindl and I am a 3rd year Ph.D. candidate working with researcher Nancy Neef in the Special Education and Applied Behavior Analysis program at The Ohio State University. As a student in the program, I am interested in conducting research that will potentially provide beneficial results for school-age student both in and out of special education. You are receiving this letter because your child’s class is one that has been identified as potential candidates for my study. Briefly, I would like to explain my study, describe your rights and your child’s rights (should you both agree to participation), and provide you with contact information should you have any questions.

This is a parental permission form for research participation. It contains important information about this study and what to expect if you permit your child to participate.

Your child’s participation is voluntary. Please consider the information carefully. Feel free to discuss the study with your friends and family and to ask questions before making your decision whether or not to permit your child to participate. If you permit your child to participate, you will be asked to sign this form and will receive a copy of the form.

Study Title: Less preferred events increase preference for subsequent stimuli

Researcher: Nancy Neef, Ph. D., & James N. Meindl, M.A.

Purpose and Duration of the Study:
The purpose of this study is to see whether students prefer items that follow less-preferred activities. For example, if the student had to engage in some difficult activity and then received a reward, is that reward more valuable because of the difficult activity? Additionally, this study intends to determine whether a student will work more for a reward that is more valuable because of the less-preferred activity.

In my study, your child will work with two different sets of math problems: less work (e.g. 5 math problems) and more work (e.g. 15 math problems). The amount of work your child likes to do will be measured. Your child will then work on each math set for an equal amount of time, followed by a task wherein your child simply selects a random shape. After completing each of the math sets and the selection task, your child’s preference for the shapes will be measured. In addition, to see whether your child will work more for one of the random shapes, he/she will be allowed to work for as much or as little as he/she wants for up to 5 minutes. Your child may stop working at any time. It is expected that your child will work more to earn access to the shape that followed the less preferred task (i.e. more work), which would mean the less-preferred task
increased preference for the shape. The total duration of the study should be no longer than 1 year, but the duration for your particular child should be no longer than 4 months. The entire study should take 1 year.

**Benefit to Your Child:**

**Your Rights:**
You or your child may refuse to participate in this study without penalty or loss of benefits to which you are otherwise entitled. If you or your child is a student or employee at Ohio State, your decision will not affect your grades or employment status.

If you and your child choose to participate in the study, you may discontinue participation at any time without penalty or loss of benefits. By signing this form, you do not give up any personal legal rights your child may have as a participant in this study.

An Institutional Review Board responsible for human subjects research at The Ohio State University reviewed this research project and found it to be acceptable, according to applicable state and federal regulations and University policies designed to protect the rights and welfare of participants in research.

**Confidentiality:**
Efforts will be made to keep your child’s study-related information confidential. However, there may be circumstances where this information must be released. For example, personal information regarding your child’s participation in this study may be disclosed if required by state law. Also, your child’s records may be reviewed by the following groups (as applicable to the research):

- Office for Human Research Protections or other federal, state, or international regulatory agencies;
- The Ohio State University Institutional Review Board or Office of Responsible Research Practices;
- The sponsor, if any, or agency (including the Food and Drug Administration for FDA-regulated research) supporting the study.

**Contacts and Questions:**
For questions, concerns, or complaints about the study you may contact _James Meindl meindl.2@buckeyemail.osu.edu_.

For questions about your child’s rights as a participant in this study or to discuss other study-related concerns or complaints with someone who is not part of the research team, you may contact Ms. Sandra Meadows in the Office of Responsible Research Practices at 1-800-678-6251.

If your child is injured as a result of participating in this study or for questions about a study-related injury, you may contact _meindl.2@buckeyemail.osu.edu_.

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PARENTAL PERMISSION
Behavioral/Social Science

Signing the parental permission form

I have read (or someone has read to me) this form and I am aware that I am being asked to provide permission for my child to participate in a research study. I have had the opportunity to ask questions and have had them answered to my satisfaction. I voluntarily agree to permit my child to participate in this study.

I am not giving up any legal rights by signing this form. I will be given a copy of this form.

Printed name of subject

Printed name of person authorized to provide permission for subject

Signature of person authorized to provide permission for subject

Relationship to the subject

Date and time

AM/PM

Investigator/Research Staff

I have explained the research to the participant or his/her representative before requesting the signature(s) above. There are no blanks in this document. A copy of this form has been given to the participant or his/her representative.

Printed name of person obtaining consent

Signature of person obtaining consent

Date and time

AM/PM
Appendix C: Verbal Assent Form
The Ohio State University Assent to Participate in Research

Verbal Assent Script

Students Age <14

Study Title: Less preferred events increase preference for subsequent stimuli

Researcher: Nancy Neef

Hello,

I am a student at The Ohio State University and I wanted to know whether you want to be in my research study. Studies are done to find better ways to treat people or to understand things better. I have already asked your parent(s) whether this is okay and they have said yes, but I want to make sure that you want to be in my study as well. It is okay to say “No” if you don’t want to be in the study. If you say “Yes” you can change your mind and quit being in the study at any time without getting in trouble. You should ask any questions you have before making up your mind and you can think about it and discuss it with your family or friends before you decide. Now let me tell you about my study to see if you are interested.

This study is to see what kinds of things you like and what kinds of things you don’t like and whether the things you like change over time. If you are in this study you will need to do some math work. Sometimes you will need to do lots of math problems and sometimes you will only do a few math problems. I will make sure the math problems aren’t too difficult so you don’t become frustrated. Sometimes you may not be able to do a math problem because it is too difficult. If this happens you can move on to another math problem. After you have finished the math problems you will then look at different shapes. You won’t be given anything else for being in the study.

It will only take you about 20 minutes to do all of this and you will do this a few times each week. My whole study won’t be longer than 1 year, but you probably won’t need to do this for longer than 4 months.

Also, if you want to stop being in my study at any time you can decide to not do the study and no one will be upset. It is entirely up to you.

Do you have any questions about my study?

Do you want to participate in my study?
Appendix D: Shape Preference Questionnaire
Initial Shape Preference Questionnaire

1. Rank these shapes in order of preference. 1 = most preferred; 4 = least preferred.

Why did you choose these shapes in this order?

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126
Terminal Shape Preference Questionnaire

1. Rank these shapes in order of preference. 1 = most preferred; 4 = least preferred.

Why did you choose these shapes in this order?

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Appendix E: Data Sheets

MSWO Data Sheet
Paired Stimulus Preference Assessment Data Sheet
Concurrent Schedule Data Sheet
Training Trials Data Sheet
# MSWO Shape Preference Assessment Data Sheet

Set: Initial Terminal

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129
Paired-Stimulus Assessment
Math Preference Assessment Data Sheet

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## Concurrent Schedule Assessment

### Reinforcer Assessment Data Sheet

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Appendix F: Sample Computer Data Output
Sample Computer Data Output from Session 13 for Participant Heinrich

Concurrent Schedule Reinforcer Assessment

4/12/2011; 2:11:41 PM
Student = Heinrich
Condition = Conc Sr Assessment
Session Number = 13
Number of Problems = Blank
Start Shape = Blank
End Shape = Blank
Left SR Shape = 8
Right SR Shape = 7
Math Type = Blank
Left Button is= Blank
Right Button is=Blank

Click Number; Time of Click
Left 1; 1
Left 2; 3
Right 1; 6
Right 2; 8
Right 3; 11
Right 4; 13
Right 5; 16
Right 6; 19
Right 7; 21
Right 8; 24
Right 9; 26
Right 10; 30
Right 11; 33
Right 12; 35
Right 13; 38
Right 14; 42
Right 15; 45
Right 16; 48
Right 17; 51
Right 18; 54
Right 19; 56
Right 20; 58

Indicates the shapes to appear when the left or right button is clicked

Indicates the Right button was clicked for the 3rd time at second 11 of the assessment