Effects of incorrect or partial implementation (poor treatment integrity) on response cost are largely unknown. We evaluated reduced treatment integrity during response cost on rates of 2 concurrently available responses. College students earned points by clicking on either a black circle or a red circle on a computer screen. Experiment 1 compared 2 types of treatment-integrity failures (omission and commission errors) across 2 levels of integrity (20% and 50%). Compared to 100% integrity conditions, omission errors did not suppress responding to the same extent, and commission errors reduced target responding but also decreased rates of alternative behavior. Experiment 2 compared the effects of 20% and 50% omission errors within subjects. Implementation at 50% integrity adequately suppressed responding, but treatment effects were lost at 20% integrity. There may be a critical level at which response cost must be implemented to suppress responding, which has important implications for application.

Key words: contrast, human operant, punishment, response cost, treatment integrity

Response cost refers to the removal of a reinforcer following a response. Response cost has successfully decreased the targeted response in highly controlled laboratory contexts (Crosbie, 1993; Pietras & Hackenberg, 2005). In addition, response cost is a common component of behavior-reduction plans in clinical contexts with children (Conyers et al., 2004; Falcomata, Roane, Hovanelz, Kettering, & Keeney, 2004), prison inmates, patients in mental health facilities, and predelinquent boys (Mazur, 2006). For example, Conyers et al. (2004) demonstrated that response-cost (token removal) procedures resulted in greater long-term suppression of disruptive behavior in a preschool classroom than differential reinforcement of other behavior.

Response cost functions as a negative punisher. Like other punishment procedures, the efficacy of response cost depends on several factors, including the frequency of reinforcer loss and the context in which the loss occurs. Response cost is most effective when each targeted response results in loss of a reinforcer. As the intermittency of response cost increases, the efficacy of the procedure decreases, so that higher schedule values (or more intermittent consequences) result in higher response rates (e.g., Pietras, Brandt, & Searcy, 2010). As the response-cost schedule becomes denser, responding is suppressed to a greater extent (Pietras et al., 2010). This finding has been
consistently demonstrated across studies in both highly controlled laboratories (Pietras et al., 2010) and in clinical applications (e.g., Clark, Rowbury, Baer, & Baer, 1973).

Intermittent schedules of response cost also may produce contrast in unpunished responding. In typical contrast research, organisms are exposed to two identical reinforcement schedules, each correlated with a distinct stimulus. After baseline responding is established on these identical schedules, one of the schedules is changed; the other remains constant. Contrast is said to occur when response rate changes on the unchanged schedule (Reynolds, 1961). Bennett and Cherek (1990) obtained positive contrast (an increase in response rate on an unchanged random-interval 20-s schedule) when they changed the response-cost schedule from variable-ratio (VR) 30 to VR 20. This change in schedule resulted in a slight increase in response rate on a component in which no response-cost procedure was in place.

The context in which response-cost procedures are implemented also may affect the extent to which targeted responding is suppressed. For example, more frequently reinforced responses are less affected by response cost than less frequently reinforced responses (Bradshaw, Szabadi, & Bevan, 1978). Understanding response cost when multiple responses are concurrently associated with different reinforcement schedules is important because these environments more closely approximate naturalistic contingencies. For example, punishment-based interventions for children who engage in problem behavior typically consist of multiple components, in which the problem behavior is punished but an appropriate alternative response is reinforced. The Professional and Ethical Compliance Code for Behavior Analysts mandates that, “If punishment procedures are necessary, behavior analysts always include reinforcement procedures for alternative behavior in the behavior-change program” (Behavior Analyst Certification Board, 2014, p. 12). Yet, much remains unknown about effects of response cost in complex environments. For example, although contrast is often shown in evaluations of response cost using multiple schedules, much of this research has focused on a single operant response (e.g., Bennett & Cherek, 1990; Brethower & Reynolds, 1962). In a notable exception, Critchfield, Paletz, MacAleese, and Newland (2003) found positive contrast when human participants’ responding on one of two concurrently available operands was punished with response cost. In this study, the punishment rate was set at 50% (for all participants) or 80% (for two participants) of reinforcement rates from a no-punishment baseline. Greater suppression of punished responding occurred during the denser punishment schedule than the leaner schedule for both participants. Increases in unpunished response rates, relative to baseline, occurred in 9 of the 10 punishment phases across participants. These results suggest that increases in unpunished responding could be a likely outcome in response-cost procedures.

Understanding effects of intermittent response cost may have important implications for application. Although response cost may be most effective when implemented on a continuous schedule, such a schedule would be difficult for caregivers to implement throughout the day with a high degree of treatment integrity. Evaluations of naturally occurring treatment integrity for intervention packages including response cost suggest that caregivers struggle with the response-cost component (Codding, Feinberg, Dunn, & Pace, 2005). Yet, the effects of inconsistent implementation, or low treatment integrity, of response cost are largely unknown.

Two commonly studied treatment-integrity failures are omission errors and commission errors. In general, omission errors occur when a consequence is not delivered according to the programmed schedule, resulting in an
unplanned reduction in the rate of consequence delivery. For example, the intermittent removal of a reinforcer when the programmed schedule of response cost was continuous (fixed-ratio [FR] 1) would be considered an omission error. Omission errors have little effect on reinforcement-based procedures (St. Peter Pipkin, Vollmer, & Sloman, 2010). However, these errors are likely to reduce the efficacy of response cost as the schedule of reinforcer loss becomes more intermittent (i.e., as omission errors become more frequent).

Commission errors occur when a consequence is delivered following an untargeted response or independently of responding. During response cost, commission errors would be said to occur if an untargeted response resulted in reinforcer loss or if a reinforcer was removed independently of responding. Commission errors are detrimental to reinforcement-based procedures (St. Peter Pipkin et al., 2010) and often result in complete loss of treatment effects. However, effects of commission errors on response-cost procedures remain largely unknown.

The purpose of the present study was to evaluate two types (omission and commission) and two levels (20% and 50%) of treatment-integrity failures during response cost using a highly controlled context. We chose to evaluate these effects using a nonclinical population and an arbitrary response instead of in a clinical context, but we attempted to make the relative schedules of reinforcement and response cost similar to those that might occur in application. In addition, we evaluated the effects of intermittent response cost on responding when multiple response options were available.

GENERAL METHOD

Participants

Nineteen college students participated in the two experiments. Table 1 shows demographic information and condition assignment for all participants. We excluded data from three participants because response rates did not decrease when response cost was implemented with perfect integrity, which precluded an evaluation of effects of integrity failures. We recruited participants through flyers posted around the university campus and an electronic recruitment website hosted by the university. Participants earned extra credit based on the duration of attendance at experimental sessions (extra credit was not based on performance). The exact amount of extra credit earned was at the discretion of the participants’ course instructors.

Apparatus

Each participant was alone in a room (4.1 m by 2.9 m) and was monitored through a one-way observation panel. The participant was seated at a computer with a monitor and mouse. The computer screen displayed two circles (one red and one black), each measuring 25.4 mm in diameter. The circles moved around the computer screen at a speed of 25.0 mm per second independently of each other. Each circle traveled in a line across the screen until it reached the edge of the screen, at which point it “bounced” in another direction. A cumulative point counter was displayed in the bottom left of the screen and was always visible to the participant. The point counter briefly flashed red each time the participant gained or lost a point.

Response Measurement

A custom-created Visual Basic computer program measured mouse clicks on each circle and on any other location of the computer screen throughout the experiment. The program also recorded each point delivery or removal. The program output all measures into an HTML file that listed the event and timestamp in milliseconds. We used these raw data to calculate response rates and obtained reinforcement
and punishment rates for each phase of the evaluation.

Procedure
Participants completed the experiment during individual appointments. Each participant completed two sessions during a single appointment. Each session lasted 60 min, which was broken into 10-min phases. For all participants, a 5-s blackout occurred after each phase, during which the screen was black and clicking did not result in any programmed consequences. Conditions were not associated with any discriminative stimuli. Participants were given a 5-min break between the sessions.

At the start of the appointment, the experimenter asked the participant to read and sign a consent form. Although the form briefly stated that the study measured how people responded to different contingencies of reinforcement, the experimenter provided no information about the particular reinforcement and response-cost schedules. After consent was obtained, the experimenter asked the participant to leave all electronic devices outside the room and read the following instructions aloud:

This is where you will be working. Remember to use only the mouse to earn as many points as possible. The instructions you see on the screen [“Click OK to begin”] are the only ones that you will get. It is up to you to figure out how to earn points. The first session is about 60 min long. At the end of that time, a thank you message will appear on the screen. When it appears, please come out and get me. You can then take your break while I reset the computer. You will do one more 60-min session before finishing the experiment. Good luck!

EXPERIMENT 1

The purpose of Experiment 1 was to evaluate omission and commission errors that occur during response cost. We used a reversal design to evaluate response cost, omission errors, and
commission errors at two levels of treatment integrity (20% and 50%). We randomly assigned participants to receive either 20% or 50% integrity; each participant experienced both types of integrity failures (omission and commission) at that single value. We selected 20% and 50% to provide a range of values and because negative effects of reinforcement-based procedures have been demonstrated when integrity levels fall below 50% (St. Peter Pipkin et al., 2010). We counterbalanced the order of conditions across sessions and participants.

We conceptualized clicking on the red circle as being analogous to an appropriate response that results in consistent, but not continuous, reinforcement. Throughout the experiment, clicking on the red circle was reinforced with one point on a variable-interval (VI) 5-s schedule that was programmed by computer selection of a random value between 1 s and 10 s for each interval. The first click to the red circle after the randomly selected duration had elapsed resulted in a point delivery. We selected a VI schedule for two reasons. First, interval schedules allow response rates to vary fairly widely without affecting reinforcement rates. In this way, interval schedules may be more sensitive at detecting history or contrast effects (St. Peter Pipkin & Vollmer, 2009). Second, we observe naturally occurring conditions that resemble interval schedules in our school-based research and consultation. That is, teachers intermittently attend to students who are on task without seeming to base their attention on the number of problems the student completed (as in a ratio schedule). This reinforcement schedule was held constant throughout the experiment to evaluate possible contrast during the response-cost phases.

We conceptualized clicking on the black circle as a form of problem behavior for which reinforcement could not be withheld, such as an automatically reinforced behavior or a severe behavior for which delivering some form of reinforcer may be necessary to ensure safety. For example, caregivers may need to physically attend to a child who engages in peer aggression maintained by adult attention to keep the peers safe. In this case, extinction (not responding to the aggression) would not be a reasonable component of a behavior plan, and the reinforcer would presumably be delivered on a continuous schedule. The contingencies in place for clicking on the black circle varied across phases but were typically ratio-based schedules. We selected ratio schedules because they seemed to approximate a condition under which a behavior was severe enough to be noticed each time it occurred. Using ratio schedules also allowed us to mirror response-dependent reinforcement conditions and response-cost conditions while adhering to best practice strategies of punishing each instance of the target behavior (e.g., Cooper, Heron, & Heward, 2007).

Phases

Baseline. During baseline, responding on each circle resulted in the delivery of points and no points were lost. Clicking on the red circle resulted in the delivery of one point on a VI 5-s schedule. Clicking on the black circle resulted in the delivery of one point on a fixed-ratio (FR) 1 schedule. These schedules were designed to approximate an intermittently reinforced appropriate response (clicking the red circle) and a form of problem behavior that was reinforced on a rich reinforcement schedule (clicking the black circle).

Response cost. During the response-cost condition, clicking on the red circle continued to result in the delivery of one point on a VI 5-s schedule. Clicking on the black circle resulted in the loss of one point (one point was deducted from the point counter on the computer screen) on an FR 1 schedule. These schedules were designed to approximate continued reinforcement for an appropriate response while
negative punishment contingencies were introduced for the problem behavior.

If participants had engaged in sufficiently high rates of responding on the black circle, the point counter would have displayed a negative number. However, this never occurred. The response-cost condition established that the participant’s behavior changed as a function of the contingencies and determined response rates that served as a comparison for the treatment-integrity evaluation.

20% integrity: Omission. The purpose of the omission phases was to examine effects of intermittent response cost for the undesirable response. As in previous phases, clicks on the red circle resulted in the delivery of one point on a VI 5-s schedule. Clicking on the black circle contacted response cost, programmed with 20% treatment integrity, which was arranged by having the computer randomly select a value between 1 and 10 and remove points if the selected value was 1 or 2. If the value was more than 2, the computer delivered a point instead of removing a point. Stated differently, four points were gained and one point was lost after approximately five clicks on the black circle. The contingencies for clicking on the black circle were designed to approximate highly intermittent response cost for a response that was otherwise reinforced.

20% integrity: Commission. The purpose of the commission phases was to examine effects of intermittent punishment of the alternative response, when consistent response cost was implemented for the undesirable response. Clicks on the red circle resulted in the delivery of one point on a VI 5-s schedule but also intermittently resulted in response cost. The response-cost contingency was programmed by having the computer randomly select a value between 1 and 10 as the schedule value for that interval. Following the first click after the schedule value was met, the computer selected another random number between 1 and 10. If the number was 1 or 2, no points were lost. If the number was larger than 2, the computer subtracted two points from the cumulative point total. These schedules resulted in the net loss of one point on four of five intervals, on average. Clicking on the black circle continued to result in the loss of one point on an FR 1 schedule. These schedules approximated frequent “accidental” application of response cost following an alternative response, as well as consistent application of response cost following the target response.

50% integrity: Omission. Clicking on the red circle resulted in the delivery of one point on a VI 5-s schedule. Clicking on the black circle contacted response cost, which was programmed by having the computer select a random number between 1 and 10 following each click to the black circle. If the computer selected a number less than or equal to 5, the computer delivered a single point. If the number was greater than 5, the computer added a point and subtracted two points, resulting in the net loss of one point. Because of the speed at which these computer operations took place, participants experienced these contingencies only as the loss of a single point following approximately every other click to the black circle. These schedules were designed to approximate a less intermittent response-cost procedure than in the 20% omission conditions.

50% integrity: Commission. Clicks on the red circle resulted in the delivery of one point on a VI 5-s schedule and also contacted intermittent response cost. Response-cost contingencies were programmed by having the computer randomly select a number between 1 and 10 each time the VI contingencies were met. The computer subtracted points from the cumulative point counter if the number was greater than 5. This resulted in one point lost for clicking on the red circle following one of two intervals, on average. Clicking on the black circle resulted in the loss of one point on an FR 1 schedule. These schedules approximated infrequent or
accidental application of response cost following an untargeted (appropriate) response, as well as consistent application of response cost following the target response.

Data Analysis

The computer program recorded instances of response cost by response in each phase so that we could evaluate the extent to which the probabilistic schedules resulted in the intended schedule values (programmed levels of integrity). We calculated obtained integrity during omission components by dividing the instances of point loss by the total number of clicks on the black circle and converting the result to a percentage. We calculated obtained integrity during commission phases by dividing the difference between the number of points delivered and the number of point deductions by the total number of points delivered for clicking the red circle, subtracting the quotient from one, and converting the result to a percentage. For example, if 100 points were delivered and there were 80 point deductions for clicking the red circle, obtained integrity levels for the phase would be 20% \((\frac{1 - 80}{100} \times 100)\).

The obtained integrity levels were not identical to the programmed values of 20% and 50% because the occurrence of integrity errors was probabilistic and dependent on participant responding. Table 2 shows the obtained integrity values. Obtained integrity values were consistently lower than 20% in the commission phases for three participants for whom the programmed integrity level was 20%. This decrease in integrity was due to very low rates of responding allocated to the red circle. The low rates of responding resulted in a small absolute number of errors constituting a large percentage of the emitted responses. For example, Participant 103 engaged in only eight red-circle clicks during the first commission phase. All of the red-circle responses that met the interval criterion were randomly selected to be punished (recall that, in this phase, eight of every 10 intervals on average resulted in point loss), resulting in seven consecutive point losses following a click to the red circle. After these responses each resulted in point loss, the participant no longer engaged in red-circle clicking. This yielded an obtained integrity value of 0%, even though the programmed value was 20%.

Results

Figures 1 through 4 show the results of Experiment 1 for individual participants. Figure 5 shows aggregated data across all participants. Data from three participants whose responding did not decrease when response cost was implemented on an FR 1 schedule are not shown. Data on the number of points that each participant earned and lost for each response type in each phase is available from the first author. Figure 1 depicts results for Participants 101, 102, and 103. These participants were exposed to the 20% integrity omission condition before the 20% integrity commission condition. During the initial baseline, Participants 101 and 103 engaged high stable rates of responding on the black circle and low stable rates of responding on the red circle. Response rates on the black circle for Participant 102 decreased for much of the first baseline phase, but increased across the last 3 min of

<table>
<thead>
<tr>
<th>Group</th>
<th>Participant</th>
<th>Omission (%)</th>
<th>Commission (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>20%</td>
<td>Average</td>
<td>21</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>101</td>
<td>21</td>
<td>18</td>
</tr>
<tr>
<td></td>
<td>102</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td></td>
<td>103</td>
<td>23</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>204</td>
<td>19</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td>205</td>
<td>20</td>
<td>0</td>
</tr>
<tr>
<td>50%</td>
<td>Average</td>
<td>50</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>301</td>
<td>54</td>
<td>49</td>
</tr>
<tr>
<td></td>
<td>302</td>
<td>44</td>
<td>47</td>
</tr>
<tr>
<td></td>
<td>303</td>
<td>54</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>404</td>
<td>49</td>
<td>56</td>
</tr>
<tr>
<td></td>
<td>405</td>
<td>50</td>
<td>59</td>
</tr>
</tbody>
</table>
the phase. The response-cost contingency suppressed response rates on the black circle for all participants. Although the reinforcement schedule for clicking the red circle remained unchanged (a VI 5-s schedule), the rate of responding increased above baseline levels for
all participants. Thus, points seemed to function as a reinforcer for all participants whose data are shown in Figure 1.

Intermittent response cost (omission errors) slightly reduced response rates from the preceding baseline during five of six
replications for Participants 101, 102, and 103, but rates were elevated well above those obtained with 100% integrity for all participants. Participant 103’s behavior seemed most sensitive to the intermittent contingency in that response rates on the black circle continued to decrease throughout the first omission-errors phase and were reduced to zero.

Figure 3. Responses across consecutive minutes for clicks on the black circle (filled circles) and the red circle (open circles) for Participants 301, 302, and 303 across baseline (BL), response cost implemented with 100% integrity (RC), 50% integrity omission condition (OE), and 50% integrity commission condition (CE).
by the third minute of the second omission-errors phase. Response rates on the red circle did not consistently increase when response cost occurred intermittently (i.e., less contrast was observed than in the FR 1 response-cost phases).
Commission errors (for which continuous response cost was applied to the black circle and intermittent response cost was applied to the red circle) decreased black-circle responding relative to the preceding baseline, but had more variable effects on red-circle responding. Response rates on the red circle increased relative to the previous baseline during the first exposure to the commission phase for Participant 101 and the second exposure to the commission phase for Participant 102, but remained lower than when response cost was implemented with 100% integrity. Responding on the red circle remained at similar levels to the preceding baseline for Participant 103 and during the first exposure for Participant 102. Responding on the red circle was more suppressed for Participant 103, who experienced an obtained integrity level of 0% in this phase, than for the other two participants, whose obtained integrity approximated the programmed level.

Figure 2 shows results for Participants 204 and 205, who experienced commission errors before omission errors. Responding for these participants resembled the response
patterns for participants who had experienced omission errors first, suggesting that condition sequence did not play a strong role in response allocation. For Participant 204, omission errors resulted in a loss of treatment effects. Commission errors maintained target response rates similar to response-cost implemented with full integrity. Commission errors resulted in lower rates of appropriate behavior relative to the 100% integrity condition but increased rates of appropriate behavior relative to baseline conditions. Thus, some amount of positive contrast was observed despite obtained commission errors occurring more frequently than was programmed.

Participant 205 engaged in highly variable responding within and across phases, making across-phase comparisons difficult. Despite the variability in responding from minute to minute, overall patterns were consistent with the other participants exposed to 20% integrity: Omission errors resulted in less response suppression than FR 1 response cost, and commission errors resulted in relatively low response rates on both circles. Relatively little positive contrast was observed in the commission phases. As with Participant 103, this lack of contrast may be due to the obtained integrity (0%) being lower than the programmed integrity in these phases.

Figure 3 shows results for Participants 301, 302, and 303, who were exposed to the 50% integrity omission condition before the 50% integrity commission condition. Figure 4 shows results for Participants 404 and 405, who were exposed to the 50% commission condition before the 50% omission condition. Patterns of results were similar to those obtained with participants exposed to 20% integrity. For all participants, response cost implemented on an FR 1 schedule suppressed punished responding to near-zero levels and increased rates of unpunished responding relative to baseline despite no change in the programmed reinforcement schedule for that response. Effects of omission errors (intermittent response cost) approximated those of FR 1 response cost in five of six replications. Response rates on the black circle were suppressed to a greater extent for participants who were exposed to 50% integrity than those who were exposed to 20% integrity, and response rates on the red circle were more likely to increase relative to baseline for participants who experienced 50% integrity than those who experienced 20% integrity. As one exception, response rates on both circles increased throughout the final omission phase for Participant 301. Commission errors resulted in suppressed response rates on the black circle for all participants. Response rates on the red circle increased during the commission-errors phase for four of five participants (301, 302, 404, 405) during at least one exposure. This effect did not occur for Participant 303, but this participant also experienced the lowest levels of obtained integrity (25% instead of the programmed 50%) during this phase.

Average effects of the types and levels of integrity failures are shown in Figure 5. Each data point depicts the average response rate of a participant during that phase, where 0% integrity indicates baseline phases and 100% integrity indicates phases in which response cost was implemented without errors. The top two graphs show results for omission phases, with clicks to the black circle shown in the left graph and clicks to the red circle shown in the right graph. Across participants, there was an orderly decrease in black-circle responding and an orderly increase in red-circle responding as the integrity level increased. Recall that these increases in red-circle responding occurred despite there being no change in the contingencies for clicking the red circle across phases.

Average effects of commission errors are shown in the lower two graphs in Figure 5. For almost all participants, phases with commission errors reduced black-circle responding nearly
equivalently to response cost implemented with perfect integrity. Increases in red-circle responding were still obtained across response-cost phases, even those that included an intermittent punishment component for responding on the red circle. Taken together, the data shown in Figure 5 suggest that, if a possible treatment integrity failure is necessary, individuals may wish to err on the side of commission errors instead of making a potential omission error.

Discussion

We evaluated the effects of intermittent response cost in concurrent schedules that may mimic those that occur in clinical contexts. When point loss followed each response, rates of punished responses were dramatically suppressed and rates of unpunished responding increased for all participants relative to the preceding baseline (although these increases were transient for Participant 303). Intermittent response cost (omission errors) resulted in graded decreases in punished responding, with response rates on the black circle reduced more for participants exposed to 50% integrity than for those exposed to 20% integrity. Similarly, intermittent response cost for the alternative response (commission errors) resulted in lower response rates on the red circle for participants who experienced point loss more often (for those who experienced 20% integrity relative to those who experienced 50% integrity), although the effect was not large. These results are consistent with previous evaluations that have demonstrated graded effects of intermittent response cost (e.g., Pietras et al., 2010).

The concurrent schedule used in Experiment 1 was designed to be analogous to the treatment of problem behavior in a clinical context. In these contexts, suppression of problem behavior may be of utmost importance. Results of Experiment 1 demonstrated that omission errors resulted in less suppression of targeted (black circle) responding than did commission errors at 20% integrity. With the exception of one phase for one participant (302), the same effect held when response cost was implemented with 50% integrity. In addition, the data suggest that omission errors are more detrimental at 20% integrity than at 50% integrity. In certain circumstances, suppression of appropriate (red circle) responding may also be problematic. When the overall reinforcement rate for appropriate behavior is low, and appropriate behavior is occasionally or inadvertently punished, appropriate responding may decrease relative to when response cost is implemented perfectly or with higher integrity. However, the comparisons across integrity values were made in a between-subjects design, so the different response rates could be attributed to individual differences in behavior. Experiment 2 compared the effect of omission errors at 20% and 50% integrity in a within-subject design.

EXPERIMENT 2

Method

Participants and setting. The setting and the recruitment process were the same as those described for Experiment 1. Six undergraduates (five female and one male) participated. Table 1 shows participant demographics. All six participants met the inclusion criterion of differentiated responding between the reinforcement and response-cost phases.

Procedure. Each participant was exposed to baseline, response cost on an FR 1 schedule, and two phases of omission errors (20% and 50% integrity). The schedule values associated with those phases were identical to those used in Experiment 1. Because commission errors did not substantially affect suppression of the black-circle clicking in Experiment 1, we did not include commission phases in Experiment 2. Each of the six participants experienced a different sequence of exposure to omission conditions.
Data analysis. Methods for data collection and analysis were identical to Experiment 1. Table 3 shows obtained integrity levels.

Results

Figures 6 and 7 show results of Experiment 2 for individual participants. Figure 6 shows results for Participants 501, 502, and 503. Figure 7 shows results for Participants 604, 605, and 606.

During baseline, all participants allocated responding primarily to the black circle; response rates on the red circle were low. Responding was initially undifferentiated for Participant 502 (Figure 6, middle) during the first and third replications of baseline, but was clearly and consistently differentiated in the other three replications of this phase. Participant 604 (Figure 7, top) engaged in variable rates of responding during the first three baseline phases, making interpretations of his results more difficult. However, mean response rates on the black circle were at least double those of response rates on the red circle during each of the first three baseline phases, and response rates were differentiated in the remainder of the baseline phases.

Response cost on an FR 1 schedule suppressed response rates on the black circle for all participants. Response rates on the red circle increased above baseline levels for all participants during response cost, suggesting that contrast may have occurred. The degree of increase was variable across participants, but was fairly stable within subjects.

When the response-cost schedule was reduced so that only 20% of responses resulted in point loss, responding allocated toward the black circle decreased relative to the immediately preceding baseline, although not to the same extent as when point loss followed each response. When response cost followed 50% of clicks to the black circle, overall response rate and allocation more closely resembled the FR 1 response-cost contingency for all participants.

To display the overall relation between treatment integrity and response rate in Experiment 2 more clearly, Figure 8 shows mean response rates by condition, with conditions along the x axis. The 0% integrity phase is the baseline condition, and the 100% integrity phase is the FR 1 response-cost condition. Each data point shows the mean response rate on the black circle for an individual participant averaged across all exposures to that condition. Response rates decreased systematically as treatment integrity increased, similar to a dose–response function. In general, response rates on the black circle were highly predictable from the level of integrity in place during the condition.

Discussion

In Experiment 2, we replicated omission effects of Experiment 1 using a within-subject design rather than a between-subjects design. Results from Experiment 2 suggest that the detrimental effects of omission errors are not due to individual differences. For five of the six participants, responding on the black circle was suppressed to a greater extent during 50% integrity than during 20% integrity. In addition, response cost implemented on an FR 1 schedule suppressed responding on the black circle and increased responding on the red circle above the optimal 12 responses per minute for all participants. This supports the

Table 3
Obtained Treatment-Integrity Values (%) for Experiment 2

<table>
<thead>
<tr>
<th>Participant</th>
<th>20%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>20</td>
<td>53</td>
</tr>
<tr>
<td>501</td>
<td>21</td>
<td>50</td>
</tr>
<tr>
<td>502</td>
<td>20</td>
<td>59</td>
</tr>
<tr>
<td>503</td>
<td>21</td>
<td>48</td>
</tr>
<tr>
<td>604</td>
<td>20</td>
<td>54</td>
</tr>
<tr>
<td>605</td>
<td>20</td>
<td>49</td>
</tr>
<tr>
<td>606</td>
<td>19</td>
<td>56</td>
</tr>
</tbody>
</table>
conclusions from Experiment 1 that omission errors may have detrimental effects on response-cost procedures, and there exists a “dose-dependent” relation between integrity of response-cost implementation and response suppression.

Figure 6. Responses across consecutive minutes for clicks on the black circle (filled circles) and the red circle (open circles) for Participants 501, 502, and 503 across baseline (BL), response cost implemented with 100% integrity (RC), 50% and 20% with omission errors.
Response-cost procedures that are implemented contingent on at least half of the occurrences of a response (50% omission integrity) may result in a reduction in the target behavior. Although it is recommended that punishers be applied after every target response (Lerman &

Figure 7. Responses across consecutive minutes for clicks on the black circle (filled circles) and the red circle (open circles) for Participants 604, 605, and 606 across baseline (BL), response cost implemented with 100% integrity (RC), 50% and 20% with omission errors.
Toole, 2011), response cost may still be effective with some integrity failures. Because omission errors involved reducing the frequency of punishment, they can be conceptualized as leaner schedules of punishment. The finding that leaner punishment schedules result in less suppression of behavior aligns with results of previous evaluations of intermittent punishment (e.g., Donaldson & Vollmer, 2012; Lerman, Iwata, Shore, & DeLeon, 1997). For example, Donaldson and Vollmer (2012) obtained consistent suppression of problem behavior when the punishment schedule was thinned from an FR 1 to a VR 2, but less consistent results when the schedule was further thinned. The within-subject differences between 20% and 50% integrity were not as clear as the between-subjects differences between 20% and 50% obtained in Experiment 1. This may be due to procedural limitations described below. However, our data provide preliminary evidence that response-cost interventions may remain effective even if only half the instances of target behavior contact the response-cost contingency.

**GENERAL DISCUSSION**

We evaluated two types and levels of treatment-integrity failures during response cost with a nonclinical population and two arbitrary responses. Across both experiments, frequent omission errors reduced the effectiveness of the response-cost procedure. These detrimental effects of omission errors waned as integrity improved. In Experiment 2, we found continued suppression when response cost occurred with 50% integrity, which is similar to a random-ratio (RR) 2 schedule, but to a much lesser extent at 20% integrity (similar to an RR 5 schedule). In contrast with positive reinforcement procedures (e.g., St. Peter Pipkin et al., 2010), commission errors did not result in increased response rates relative to the perfect-integrity conditions, regardless of the programmed integrity level.

Our findings demonstrate that different forms of errors may lead to different treatment outcomes. Thus, when one is faced with a potential treatment-integrity failure, the best course of action may depend on the priorities of the treatment agent. For example, presume a teacher implements a token-based response cost in her classroom for talking out without permission. While she is attending to another student, she thinks she hears a student talk out. Should the teacher remove a token? The answer to this question may depend on the teacher’s priorities. If near-elimination of problem behavior is of utmost importance, the teacher may want to remove the token even if she’s not entirely sure that the problem behavior met criterion. In Experiment 1, incorrect removal of a point (a commission error) resulted in some suppression of appropriate responding but continued near-elimination of problem behavior. If a high rate of appropriate responding is important, the teacher should consider ignoring the instance of talking out (a potential omission error). Our data suggest that, as long as the teacher catches at least 50% of the instances of
talking out, problem behavior is likely to remain relatively suppressed. However, it is unclear from our data the extent to which the findings are an interaction between the programmed schedules and the types of integrity failures. Different outcomes may have been obtained if we initially reinforced both responses on ratio schedules or if integrity failures occurred on an interval-like schedule instead of a probabilistic schedule. Future research could further explore these possible interactions. Also, our study involved a non-clinical population and an arbitrary, low-effort response. The external validity of our results still needs to be established. Future research should replicate our findings with clinically significant populations, responses, and settings. In these studies, researchers should consider including an evaluation of possible side effects of errors. It is possible that commission errors produce more negative side effects, including undesirable emotional responding, than do omission errors.

Across both experiments, we saw evidence of positive contrast. That is, responding on the red circle, our analogue to appropriate behavior, increased when response cost was implemented with high integrity. This increase in response rate occurred even though the contingency in place for clicking the red circle remained constant across the study. Obtaining positive contrast or induction of unpunished responding has been idiosyncratic in previous studies. Contrast or induction effects may be due to each individual’s sensitivity to the punisher used. For example, Crosbie, Williams, Lattal, Anderson, and Brown (1997) suggested that induction was obtained in their evaluation of human responding during response cost because they individually determined the magnitude of the response cost for each participant. In the current study, a weak punisher (loss of points that were not exchangeable for backup reinforcers) was used for all participants. We obtained contrast for all participants despite the use of a relatively weak punisher that was not individually determined.

Further exploration of the conditions under which contrast and induction occur is warranted. Effects of response cost on unpunished responding could have important implications for application. For example, appropriate behavior may increase when undesired behavior is punished with response cost, even if the programmed reinforcement schedule for appropriate responding does not change. Such increases in appropriate behavior may be desirable in some circumstances and may not require any extra response effort on the part of the treatment agent.

The current study was designed to evaluate variations on response-cost procedures in a highly controlled experimental context. To this end, we selected a nonclinical participant sample who engaged in response rates that substantially exceeded those typically found in treatment contexts and used an arbitrarily selected consequence (point delivery and removal). In addition, the topography of the response was identical (a mouse click) for both problem behavior (black-circle clicks) and appropriate behavior (red-circle clicks). This similarity in topography would be unusual in the treatment of socially significant behavior, in which replacement behavior (e.g., vocal communication) is often a very different topography than problem behavior (e.g., aggression). Basic studies have shown that similarity of response topography can affect reemergence of the response after suppression (Doughty, da Silva, & Lattal, 2007). It is possible that we would have obtained different results if our response topographies had been more distinct. Thus, although our procedures were informed by applied issues, the extent to which our findings would generalize to clinical contexts is unknown. However, previous studies have demonstrated that human operant results can be applicable to clinical populations. For
example, St. Peter Pipkin et al. (2010) and Marsteller and St. Peter (2012) replicated their human operant findings on treatment-integrity failures during clinical treatment.

The current findings are limited because responding was sometimes in transition when the reinforcement schedules changed. The fixed duration of the phases sometimes resulted in phase changes occurring before response rates stabilized. For example, response rates for Participant 102 decreased across the first 7 min of the initial baseline, and black-circle responding failed to recover during the second baseline phase for Participant 203. In addition, responding was often variable during the integrity-failure phases. Despite this variability in moment-to-moment response rates, general response patterns were replicated within and across participants, suggesting that the effects demonstrated were due to the contingencies in effect rather than extraneous variables.

The present study evaluated only 20% and 50% treatment integrity. Therefore, the detrimental effects of integrity errors at other levels of integrity (e.g., 40%) are unknown. Given that omission failures resulted in a loss of treatment effects at 20% integrity but not at 50% integrity, knowledge of a possible “critical integrity value” for response cost may be useful. Researchers should investigate effects of other treatment-integrity levels (e.g., between 20% and 50%). In addition, we evaluated omission and commission errors separately, but it is unlikely that each kind of error would occur in isolation during clinical implementation of response cost. The combined effects of omission and commission errors are another area for further response-cost research. This information would inform clinicians’ decisions to select a response-cost procedure, problem solving regarding ineffective response-cost procedures, and training of stakeholders to implement response-cost procedures.

Future research should also evaluate omission and commission errors during response cost with children and adults who engage in problem behavior. Replications of the findings from this study in a treatment context would further emphasize the importance of treatment integrity when response-cost procedures are implemented. In addition, replications would provide further support for the value of human operant evaluations of conditions analogous to the treatment of problem behavior.

REFERENCES


Received February 20, 2015
Final acceptance August 12, 2015
Action Editor, Jeanne Donaldson