

“WATCH OUT!”: EFFECTS OF INSTRUCTED THREAT AND AVOIDANCE ON
HUMAN FREE-OPERANT APPROACH–AVOIDANCE BEHAVIOR

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Approach–avoidance paradigms create a competition between appetitive and aversive contingencies and are widely used in nonhuman research on anxiety. Here, we examined how instructions about threat and avoidance impact control by competing contingencies over human approach–avoidance behavior. Additionally, Experiment 1 examined the effects of threat magnitude (money loss amount) and avoidance cost (fixed ratio requirements), whereas Experiment 2 examined the effects of threat information (available, unavailable and inaccurate) on approach–avoidance. During the task, approach responding was modeled by reinforcing responding with money on a FR schedule. By performing an observing response, participants produced an escalating “threat meter”. Instructions stated that the threat meter levels displayed the current probability of losing money, when in fact loss only occurred when the level reached the maximum. Instructions also stated pressing an avoidance button lowered the threat level. Overall, instructions produced cycles of approach and avoidance responding with transitions from approach to avoidance when threat was high and transitions back to approach after avoidance reduced threat. Experiment 1 revealed increasing avoidance cost, but not threat magnitude, shifted approach–avoidance transitions to higher threat levels and increased anxiety ratings, but did not influence the frequency of approach–avoidance cycles. Experiment 2 revealed when threat level information was available or absent earnings were high, but earnings decreased when inaccurate threat information was incompatible with contingencies. Our findings build on prior nonhuman and human approach–avoidance research by highlighting how instructed threat and avoidance can impact human AA behavior and self-reported anxiety.

Key words: instructed threat, anxiety, approach–avoidance, conflict decision making

One of many consistent themes in Psychology is that human behavior is determined by competing variables. For instance, Freud (1924) theorized neurosis reflected a disturbance in the relation between the conflicting energies of the ego and its id. The relation between competing approach and avoidance behaviors (or approach–avoidance/AA) later

gained prominence in many different psychological disciplines (Elliott, 2008; Elliott & Church, 1997; Lang, 1995). Currently, several contemporary personality and neurophysiological theories view AA conflict as a competition between inner dispositions, emotions or motivations to pursue reward and to run from or escape harm (Gray, 1985; Gray & McNaughton, 1996; Lang & Bradley, 2008; Larsen & Augustine, 2008). From a behavior analytic perspective, AA conflict and associated anxiety may be viewed as a competition between appetitive and aversive contingencies for behavioral control.

Nonhuman research on AA has advanced our understanding of the behavioral and neural mechanisms of anxiety and action of anxiolytic drugs (Amemori & Graybiel, 2012; Lippa, Klepner, Yunger, Sano, Smith, & Beer, 1978; Rowlett, Lelas, Tornatzky & Licata, 2006). Many studies examine responding under conditions where there is a proximal

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contrast between appetitive and aversive stimuli that produces a conflict, which elicits anxiety and motivates avoidance (Botvinick, 2007). For example, in the Vogel Conflict Test water-deprived rats are offered a water bottle in which licks (approach behavior) are accompanied by water and periodic punishing electric shocks (Vogel, Beer & Clody, 1971). As shock intensity increases, an AA transition point is reached whereby licking ceases, revealing the shock intensity associated with peak anxiety and shift in behavioral control from water to shock. Functionally similar disruptions of operant behavior occur in studies on conditioned suppression to cues correlated with an upcoming unavoidable shock. Cue presentation disrupts appetitive responding, often as decreases in response rate, and generates fear and anxiety, inferred from increases in freezing or defecation, prior to shock delivery (Estes & Skinner, 1941; Rescorla & LoLordo 1965).

While nonhuman research on AA and anxiety is well established, the challenges associated with bridging nonhuman and human research and understanding the role of uniquely human characteristics, such as instruction following (e.g., Baron & Galizio, 1983; Galizio, 1979), in AA and anxiety are only now being explored (Aupperle & Martin, 2010; Aupperle, Sullivan, Melrose, Paulus, & Stein, 2011; Aupperle, Melrose, Francisco, Paulus, & Stein, 2015; Bach et al., 2014; Schlund et al., 2016; Schlund & Cataldo, 2010; Schlund, Magee & Hudgins, 2011; Schlund et al., 2010; Sierra-Mercado et al., 2015). Human research targeting issues of joint control by appetitive and aversive contingencies could potentially make novel contributions to contemporary behavioral and neurophysiological theories of anxiety and the development of an empirically grounded model of the endophenotypic expressions of pathological avoidance in anxiety disorders (Schlund, Brewer, Richman, Magee & Dymond, 2015). Behavior analysis may therefore play a role in translating lay descriptions and cognitive conceptualizations of AA processes in anxiety into constituent behavioral and motivational processes in ways that foster interdisciplinary research on anxiety disorders (Critchfield, 2011; Dymond & Roche, 2009; Lewon & Hayes, 2014).

In this regard, recent developments in human behavioral and neurophysiological investigations of AA are noteworthy and of relevance to translational research (Aupperle et al, 2015; Bach et al., 2014; Schlund et al., 2016). For example, Sierra-Mercado et al. (2015) developed a task for use with humans and nonhumans called the Avoidance–Reward Conflict (ARC) paradigm. The ARC is a discrete trial, two-choice (approach/avoid) discrimination task that varies reward magnitude (money/food) and probability of an aversive air puff to the eye. On each trial, a compound stimulus is presented highlighting both the reward magnitude and probability of an air puff. Participants chose between the reward (approach) and trial termination (avoidance). Results from adult humans and monkeys (*Macaca mulatta*) show that while increases in the probability of the air puff produce a transition from approach to avoidance, increasing reward magnitude reduces avoidance and increases approach responding.

Learning about environmental threats by instructions or via other vicarious pathways such as observational learning can facilitate and maintain fear and avoidance in humans (e.g., Cameron, Roche, Schlund, & Dymond, 2016; Dymond, Schlund, Roche, De Houwer, & Freegard, 2012; Olsson & Phelps, 2007; Rachman, 1977; Raes, De Houwer, De Schryver, Brass, & Kalisch, 2014). Indeed, the ability of humans to socially transmit information about threatening or dangerous stimuli such as through instructions and how to behave consistently with such information has great survival value (Lindström & Olsson, 2015). In research on “instructed fear learning” for example, researchers present instructions describing upcoming pairings of conditioned stimuli (CSs) and shock (US; unconditioned stimuli) and either (a) deliver shock or (b) never expose subjects to shock. Both approaches support fear learning as evidenced by increased electrodermal activity and elevated self-reported US expectancy to CSs. What is currently unclear is the extent to which providing instructions about CS–US (threat) relations affect human AA behavior. Presumably repeated CS presentations without US delivery will result in extinction and undermine control by instructed threat as US delivery is not consistent with instructions

(see Kryptos, Arnaudova, Effting, Kindt, & Beckers, 2015). Accordingly, in the present study we hypothesized instructions about threat (e.g., “the red light precedes shock”) when an aversive stimulus is not delivered, along with instructions about the avoidance response/contingency (e.g., “press button A to reduce your chances of being shocked”) will together function to maintain human AA behavior. Under these conditions, the consistent absence of the aversive stimulus following avoidance will be consistent with instructions and potentially function as a negative reinforcer for avoidance and continued instruction following (Baron & Galizio, 1983; Galizio, 1979; Kryptos, Effting, Arnaudova, Kindt & Beckers, 2014).

The present investigation was designed to advance our understanding of the role of instructed threat and avoidance in maintaining human AA behavior. In contrast to prior studies that have used discrete trial procedures (Aupperle et al., 2015; Bach et al., 2014; Schlund et al., 2016; Sierra-Mercado et al., 2015), we examined the utility of a free-operant AA procedure that captures the effects of an appetitive-aversive competition on AA behavior present in many naturalistic situations. Figure 1 provides a conceptual model of human AA along with key behaviors (approach, observing, avoidance) and contingencies used in our laboratory task. As shown in Figure 1, approach responding was modeled by reinforcing button pressing with money on a fixed-ratio (FR) schedule, in which money was delivered following a fixed number of button presses. A separate observing button was also included to measure the frequency of actively attending to and pursuing information about threat. Pressing the observing button produced a “threat meter” that escalated from 0 to 100 gradually over time. Instructions stated the meter level displayed the current chance of losing money, when in fact money loss *only* occurred when the level displayed reached 98. Instructions also stated that the threat level displayed could be lowered by pressing an avoidance button. Prior behavioral research showing temporal control of avoidance behavior (Anger, 1963; Baron & Galizio, 1976; Hine-line, 1970; Hine-line & Herrnstein, 1970; Sidman, 1962a,b) predicts that as the level or probability of threat steadily increases over time, aversive control—here, established through instructions—would eventually surpass

control by the appetitive contingency, producing an ‘Approach to Avoidance’ transition that reflects the upper threshold of control by instructed threat. As avoidance responding is negatively reinforced by reducing the displayed threat level, aversive control would eventually give way to control by the appetitive contingency, producing an ‘Avoidance to Approach’ transition that reflects the lower threshold of control by instructed threat. Across two experiments, we examined the effects of instructed threat and avoidance on human AA behavior and a number of additional variables we hypothesized would impact control.

Experiment 1

While our overall goal was to examine the effects of instructed threat, Experiment 1 additionally examined the effects of threat magnitude (i.e., money loss amount) and cost to engage in avoidance (i.e., increased FR responding) on AA transitions, frequency of observing and monetary earnings. Specifically, we examined whether increases in threat magnitude and avoidance cost would enhance aversive control, resulting in AA transitions occurring at lower threat levels and increasing the frequency of observing.

Method

Participants. Participants were recruited by flyers and consisted of 16 adults ($M_{\text{age}} = 23.1$, $SD = 2.1$, 6 males) who reported being free of psychiatric disorders, brain insult, use of medications capable of altering central nervous system functioning, extensive prior research experience, and extensive (monthly) prior exposure to academic psychology. All provided written informed consent. Participants were compensated \$5.00 USD for participation and earned additional money during the experimental task. Participation lasted one 2 hr session. The Institutional Review Board for the Protection of Human Subjects approved this investigation.

Apparatus. The experiment took place in a small windowless room containing a desk, computer monitor, chair, and standard keyboard. Responses were made with the right hand on a number pad. Experimental events were programmed and data collected with custom software written in the Eprime[®] platform.

REDUCED by pressing the #3 = Reduce button (2 or 20) times. When the level is where you want it, pressing 1 will return the 1 = Money button.

So: you can press button “#1 = Money” to earn money, press “#2 = Switch” to see the threat level and press “#3 = Reduce” to lower the threat level.

NOTE: You decide when and how often to press the buttons.

Any questions?”

Task. Figure 2 presents a detailed schematic of the AA task. During the phase depicted in Figure 2A, pressing the approach button produced money (\$0.10) on a fixed-ratio 25 (FR25) reinforcement schedule. A single press on the observing button in the phase shown in Figure 2B produced a “threat meter” and a *reduce* (avoidance) button. The threat level on the meter ranged from 0 to 100 and gradually increased over time, beginning at threat level 2 and increasing by a step size of 4 every 2 s—thus, taking ~49 s to reach 100. Instructions stated that the threat level displayed represented how likely it was that the participant could lose money. Unbeknownst to participants, only when the threat level reached 98 did a “Lose \$0.25” prompt appear for 1 s and reappeared every 1 s until avoidance responding reduced the level below 98 (i.e., a 1-s loss-loss interval). Figure 2C highlights the choice phase where participants could either press the approach button or press the avoidance button. Instructions stated that the threat level displayed could be reduced by pressing the avoidance button (2 or 20) times. No changeover delay was used.

Verbal reports. As a manipulation check for our instructions about threat, participants completed pencil and paper questionnaires that assessed their anxiety levels after completing each condition in the terminal block. Anxiety ratings were obtained using a 9-point Likert scale (1 = low, 9 = high). Participants were instructed to “Please use the Likert scales to rate your anxiety level when the threat meter level was at its highest level and at its lowest level.”

Data analyses. Group and individual subject analyses focused on the effects of cost and threat magnitude on four dependent measures: (a) anxiety ratings, (b) threat levels associated with AA transitions during ‘Approach to Avoidance’ and ‘Avoidance to Approach,’ (c) frequency of observing and (d) earnings. For each dependent measure, we employed a 2×2 repeated-measures analysis of variance (ANOVA) with avoidance cost (FR2, FR20), and threat magnitude (\$0.01 loss, \$0.40 loss) as within-subject factors and a criterion alpha set at $p < .05$. Post-experiment anxiety ratings were also evaluated within conditions using paired sample *t*-tests with a criterion alpha set at $p < .05$ with Bonferroni correction. Observing was examined by categorizing observing responses into one of two categories. The first category was characterized by the frequency of engaging in approach responding, observing threat and then returning to approach responding or ‘Approach: Observe:Approach’. The second category was characterized by the frequency of engaging in approach responding, observing threat and then initiating avoidance responding or ‘Approach:Observe:Avoid’.

Stability criteria. Stability for each subject in each condition was assessed post-hoc using earnings, with stability considered to be no more than a 15% difference between earnings in the second block relative to the mean of the first and second blocks. Additionally, significant changes in earnings within conditions were assessed using paired sample *t*-tests with a criterion alpha set at $p < .05$ with Bonferroni correction.

Results and Discussion

Due to a computer error, data from three subjects for two experimental conditions were lost, but their remaining data are shown in plots containing individual subject data.

Verbal reports. Figure 3 and Table 1 provide individual subject and group mean anxiety ratings for when threat was at its highest and lowest for each condition. These findings provide an important manipulation check of our instructions about threat. Specifically, did threat instructions relating increases in threat level with increases in the chances of money loss effectively establish higher levels of threat as more aversive than lower levels? In all

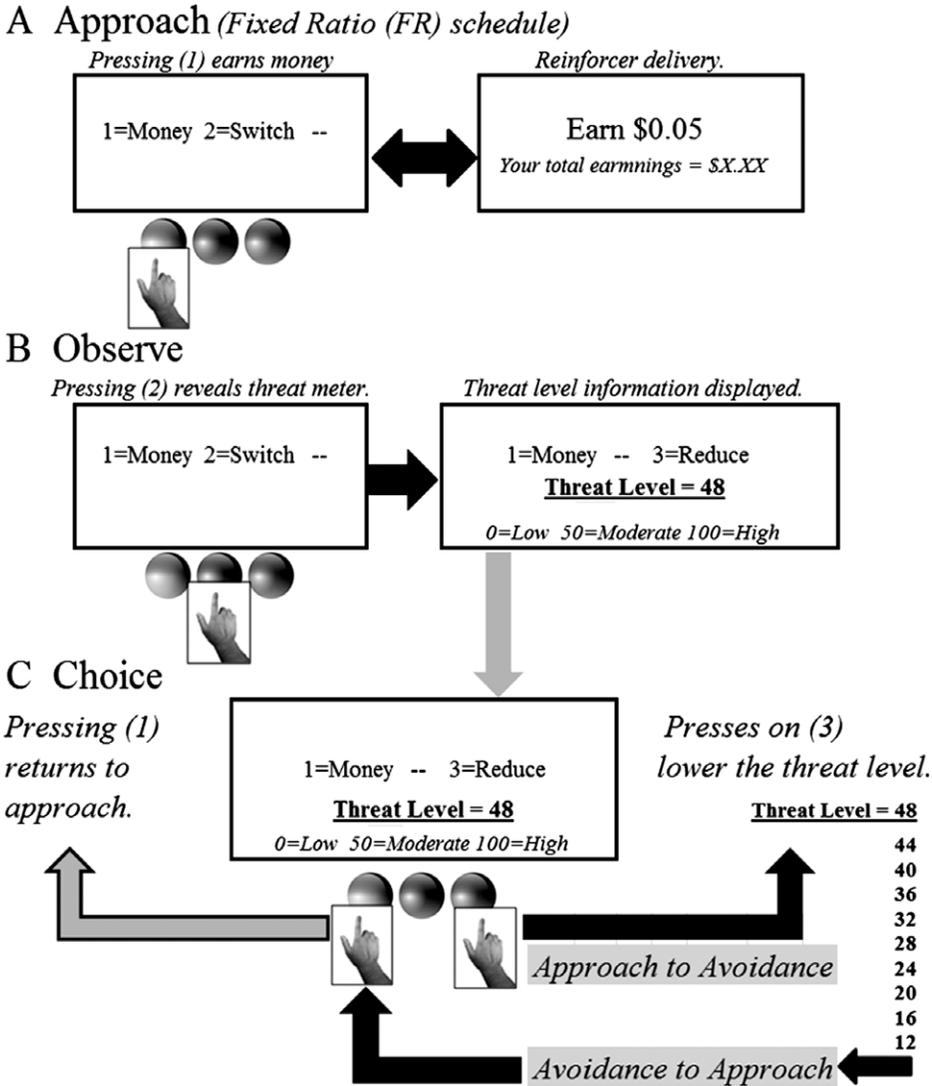


Fig. 2. General schematic of AA task. [A] Responding on button #1 produced money on an FR schedule. [B] A single press on observing button #2 revealed a threat meter and a “3 = Reduce” avoidance button. Instructions stated the threat meter displayed the current threat level (range 0–100) which increased over time and reflected the likelihood of money loss. In addition, pressing the avoidance button lowered the level. [C] Participants could either press #1 to return to [A] or button #3 to reduce the threat level. When the threat level reached 98, a 1-s “Lose \$0.25” prompt appeared every 1 s (i.e., a 1-s shock-shock interval) until the level was reduced below 98 through avoidance. No changeover delay was used.

conditions we found that the highest experienced threat level was associated with significantly greater anxiety compared to the lowest experienced threat level (see Table 1). Additionally, results showed that when threat levels were low, there was no significant main effect of avoidance cost ($F(1, 12) = 2.182, p = .165$), threat magnitude ($F(1, 12) = 0.00, p = 1.0$) or interaction ($F(1, 12) = 0.00, p = 1.0$). However,

when threat levels were high, we found a significant main effect of avoidance cost ($F(1, 12) = 5.108, p = .043$) but no effect of threat magnitude ($F(1, 12) = 2.695, p = .127$) or interaction ($F(1, 12) = 1.558, p = .235$). These group findings show that when the threat level was high increasing avoidance cost from FR2 to FR20 was associated with an increase in ratings of anxiety.

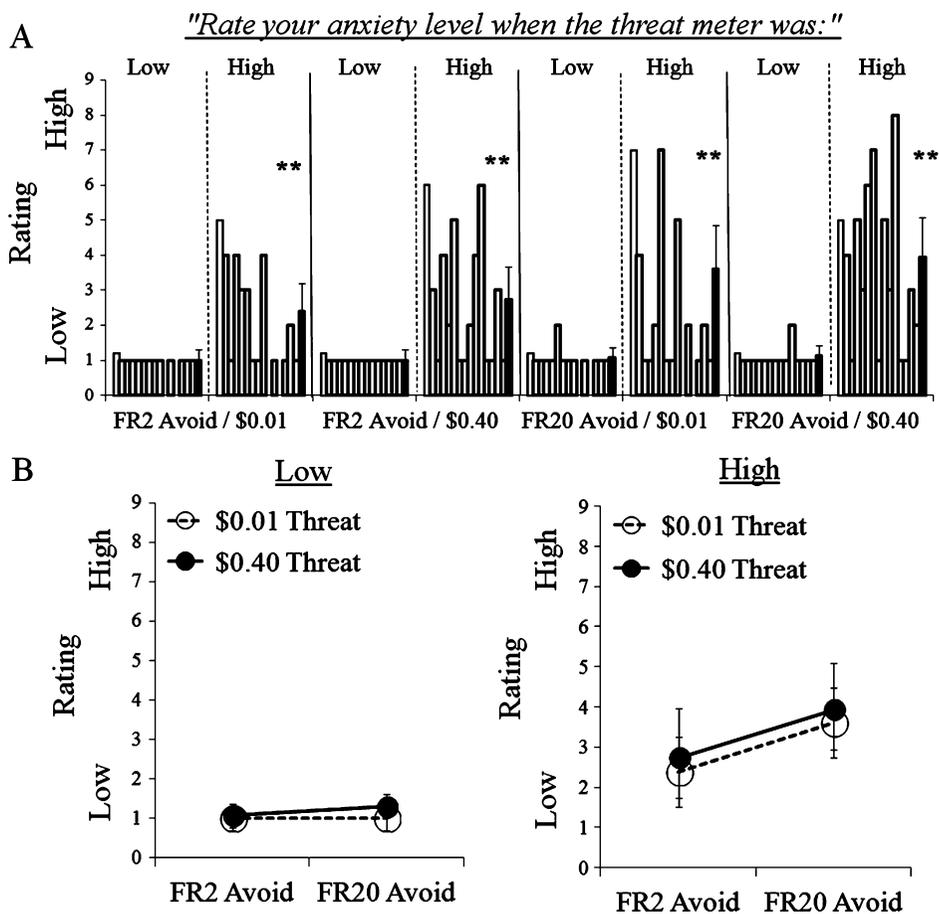


Fig. 3. Verbal reports of anxiety level for Experiment 1. A within-subjects 2 x 2 factorial design incorporated two levels each of threat magnitude (\$0.01 loss, \$0.40 loss) and avoidance cost (FR2, FR20) creating four experimental conditions. [A] Individual participant anxiety ratings for each condition. Within conditions, higher threat levels were associated with significantly higher ratings of anxiety compared to low threat levels, supporting the efficacy of our threat instructions in establishing higher levels of the threat meter as aversive. (Open bars represent participants. Filled bars represent group means. Error bars represent 95% confidence intervals. $**p < .05$ Bonferroni corrected.) [B] Group means for anxiety ratings when threat was low (left panel) and high (right panel).

AA transitions. Figure 4 displays cumulative records highlighting cycles of AA behavior and associated changes in the threat level displayed. Columns present results from two experimental conditions (left: FR2 Avoid with a \$0.40 loss; right: FR20 Avoid with a \$0.40 loss) for a representative participant. Top and middle rows show cumulative and total number of approach and avoidance responses over a 100-s period. Approach responding was reinforced with money on an FR25 schedule. Avoidance responding was reinforced with incremental threat level reductions on an FR2 or FR20 schedule. Results show cyclical

response patterns characterized by regular alternating bouts of approach and avoidance responding. The bottom row shows the changes occurring in the threat level displayed over time, with the level steadily increasing over time and subsequently decreasing when participants responded to complete FR2 and FR20 avoidance schedules.

Group and individual participant results suggest that increasing from FR2 avoidance to FR20 avoidance weakened control by instructed threat, but increasing the threat magnitude from \$0.01 to \$0.40 did not. Figure 5 and summary Table 2 present group

Table 1
t-Test Results for Post Condition Anxiety Ratings

Condition	Level	Anxiety		<i>t</i>	df	<i>p</i>
		<i>M</i>	<i>SD</i>			
FR2 / \$0.01	Low	1.00	0.05	3.2	12	0.004
	High	2.38	1.56			
FR2 / \$0.40	Low	1.00	0.04	3.6	12	0.002
	High	2.73	1.79			
FR20 / \$0.01	Low	1.08	0.28	3.7	12	0.001
	High	3.62	2.50			
FR20 / \$0.40	Low	1.13	0.52	4.4	12	<.001
	High	3.93	2.43			

mean and individual participant threat levels that were associated with switching from 'Approach to Avoidance' and 'Avoidance to Approach'. For 'Approach to Avoidance' transitions, increased FR avoidance cost resulted in an increase in the threat level at which transitions occurred. We found a significant main effect of avoidance cost ($F(1, 12) = 26.32$, $p < .0001$) but no effect of threat magnitude ($F(1, 12) = .095$, $p = .764$), or interaction ($F(1, 12) = .051$, $p = .825$). There was a notable consistency with increased FR avoidance cost pushing AA transitions to higher threat levels and increasing anxiety ratings. For 'Avoidance to Approach' transitions, increased avoidance cost also resulted in an increase in the threat level at which AA transitions occurred, again consistent with weakened control by instructed threat. We found a significant main effect of avoidance cost ($F(1, 12) = 18.068$, $p < .001$), but not threat magnitude ($F(1, 12) = .004$, $p = .948$) or interaction ($F(1, 12) = 1.784$, $p = .206$). These group effects of avoidance cost are also noticeable at the individual participant level.

Observing. Overall, group and individual participant analyses of observing and the frequency of AA cycles revealed no changes as a function of increasing from FR2 to FR20 avoidance or increasing threat magnitude from \$0.01 to \$0.40. Figure 6 presents group and individual participant observing frequencies for Approach:Observe:Approach and Approach:Observe:Avoid. It is important to note the frequency of Approach:Observe:Avoid patterns also highlights the frequency of AA cycles. Group analyses of the frequency of Approach:Observe:Approach patterns showed no significant main effect of avoidance cost

($F(1, 12) = .787$, $p = .393$) or threat magnitude ($F(1, 12) = 4.472$, $p = .056$). Similarly, group analysis of the frequency of Approach:Observe:Avoid patterns showed no significant main effect of avoidance cost ($F(1, 12) = 1.833$, $p = .201$) or threat magnitude ($F(1, 12) = 1.277$, $p = .281$). The absence of significant group effects is supported by individual participant analysis.

Earnings. Figure 7 shows group mean and individual participant earnings declined from FR2 to FR20 avoidance but not when threat magnitude increased from \$0.01 to \$0.40. Analysis of total earnings did reveal a significant main effect of avoidance cost ($F(1, 12) = 11.093$, $p = .006$), no main effect of threat magnitude ($F(1, 12) = 2.07$, $p = .176$) but an interaction ($F(1, 12) = 7.01$, $p = .021$). However, these results are not surprising given that increasing cost from FR2 to FR20 increased the time spent avoiding which leaves less time to engage in approach, thereby reducing reinforcement rates.

Overall, there was a reasonable amount of stability in earnings at the individual and group level between blocks of each condition (corrected at $p = .0125$). In the FR2 avoidance / \$0.40 loss condition 75% (12/16) of participants met the stability criterion and mean earnings did not significantly change between blocks ($t(15) = 1.65$, $p = 0.12$). In the FR2 avoidance / \$0.01 loss condition 85% (11/13) of participants met the stability criterion and mean earnings did not significantly increase between blocks ($t(12) = 2.30$, $p = .04$). In the FR20 avoidance / \$0.40 loss condition 69% (11/16) of participants met the stability criterion and mean earnings did not significantly change between blocks ($t(15) = 0.07$, $p = .94$). Finally, in the FR20 avoidance / \$0.01 loss condition 85% (11/13) of participants met the stability criterion and mean earnings did not significantly change between blocks ($t(12) = 1.87$, $p = .09$).

Experiment 2

Previous research on instructional control has shown that when instructions and schedule contingencies are incompatible, such that instruction-following does not produce sufficient levels of positive or negative reinforcement or is otherwise punished, responding will shift from control by instructions to

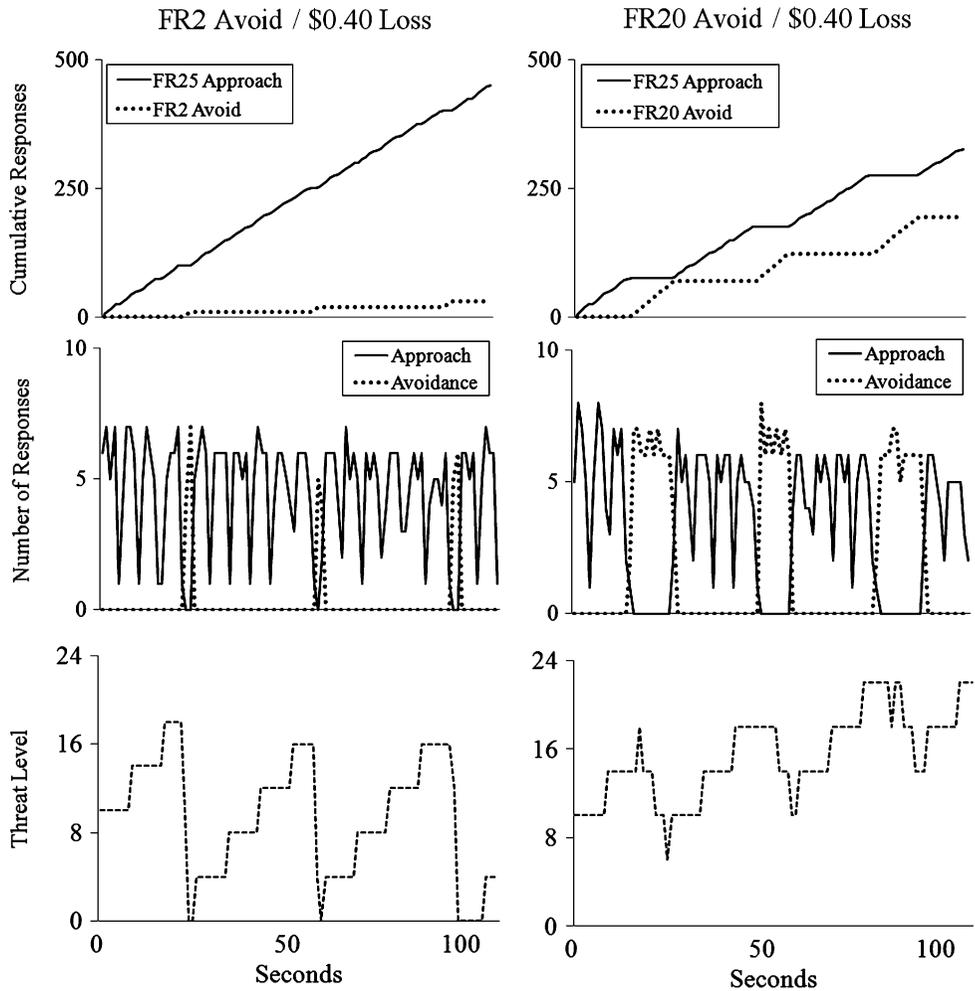


Fig. 4. Cycles of human approach-avoidance behavior during Experiment 1. Columns present results from two experimental conditions (left: FR2 Avoid with a \$0.40 loss; right: FR20 Avoid with a \$0.40 loss) for a representative participant. Top and middle rows show cumulative and total number of approach and avoidance responses over a 100-s period. Approach responding was reinforced with money on an FR25 schedule. Avoidance responding was reinforced with incremental threat level reductions on an FR2/20 schedule. Results show cyclical response patterns characterized by regular alternating bouts of approach and avoidance responding. The bottom row shows the changes occurring in the threat level displayed over time, with the level steadily increasing over time and subsequently decreasing while participants responded to complete FR2 and FR20 avoidance schedules.

schedule contingencies (Baron & Galizio, 1983; Galizio, 1979). Experiment 2 was designed to examine the effects of available, unavailable and inaccurate threat information on AA behavior. We hypothesized that when the threat meter was unavailable or displayed inaccurate information, AA transitions may shift to lower threat levels accompanied by increases in the frequency of observing and reductions in earnings. Experiment 2's examination of the effects of accurate threat information also provides an opportunity to

replicate findings showing control by instructed threat reported in Experiment 1.

Methods

All aspects of the experiment mirrored those of Experiment 1 except as noted. Fifteen adults ($M_{\text{age}} = 28.9$, $SD = 4.4$, six males) participated. None participated in Experiment 1. All provided written informed consent. The Institutional Review Board for the Protection of Human Subjects approved this investigation.

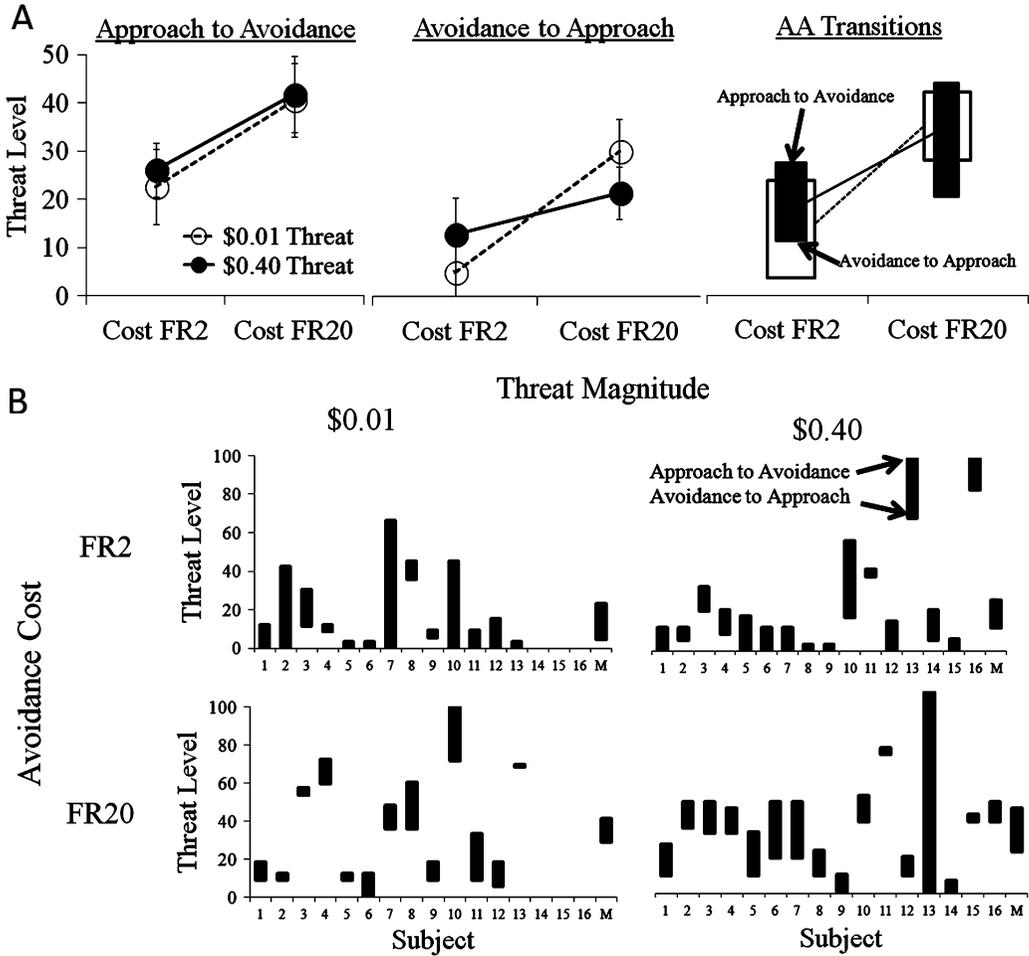


Fig. 5. AA transitions during Experiment 1. [A] AA transition points that reflect threat levels associated with >50% probability of switching from ‘Approach to Avoidance’ (left plot) and >50% probability of switching from ‘Avoidance to Approach’ (middle plot) and combined (right plot). For both transitions, significant increases in threat level were observed with increased avoidance cost (FR2 to FR20) but not threat magnitude (\$0.01 to \$0.40). (Bars represent 95% confidence intervals.) [B] Threat levels for individual participant AA transitions for each experimental condition. (M = group mean)

Three experimental conditions (Available, Unavailable, Inaccurate) were created by manipulating instructions about the accuracy and availability of threat information displayed on the threat meter. A within-subjects design was used. Conditions were presented randomized in a block. Three blocks were completed, with results presented for the third block. Each condition ended after 5 min. For all conditions, avoidance responding on an FR2 schedule reduced the threat level by a step size of 2 and money loss was set to \$0.21. Approach responding was reinforced with

\$0.07 on a FR35 reinforcement schedule. Across all conditions the *programmed* threat level increased two steps every 4 s and avoidance on an FR2 decreased the level by one step. Again, a 1-s loss-loss interval (loss of \$0.21) was triggered when the programmed threat level reached 98. In the Available condition, the threat meter displayed changes in the *programmed* threat level (i.e., the same as Experiment 1). However, in the Unavailable condition the threat meter display was blank, but changes in the *programmed* threat level still occurred. Finally, in the Inaccurate condition

Table 2
Performance summaries for experiment 1.

Condition	Participant	Total Approach	Total Observe	Total Avoid	Reinforcers per Minute	Earnings (USD)	Session Duration (mins)
FR2 / \$0.01	1	1125	13	66	10.6	\$2.25	4.25
	2	1125	6	67	9.0	\$2.25	5.00
	3	1125	15	68	10.3	\$2.25	4.38
	4	1125	8	12	12.2	\$2.25	3.68
	5	1125	11	65	10.3	\$2.25	4.35
	6	1125	7	46	9.4	\$2.25	4.80
	7	1125	6	39	11.4	\$2.25	3.95
	8	1125	33	68	13.6	\$2.25	3.30
	9	985	5	76	7.8	\$1.94	5.00
	10	1125	13	60	10.8	\$2.25	4.18
	11	1125	9	43	11.5	\$2.25	3.90
	12	1125	54	60	9.9	\$2.25	4.55
	13	1125	7	65	10.6	\$2.25	4.23
	14	—	—	—	—	—	—
	15	—	—	—	—	—	—
	16	—	—	—	—	—	—
FR20 / \$0.01	1	1050	18	360	8.4	\$2.10	5.00
	2	700	5	602	5.6	\$1.40	5.00
	3	935	6	647	7.4	\$1.85	5.00
	4	1125	8	258	11.0	\$2.25	4.10
	5	809	15	703	6.4	\$1.60	5.00
	6	953	6	364	7.6	\$1.90	5.00
	7	1060	11	424	8.4	\$2.10	5.00
	8	1125	18	590	11.8	\$2.25	3.82
	9	512	30	712	4.0	\$1.00	5.00
	10	925	10	389	7.4	\$1.85	5.00
	11	1125	10	320	9.9	\$2.25	4.55
	12	650	54	695	5.2	\$1.30	5.00
	13	922	12	652	7.2	\$1.80	5.00
	14	—	—	—	—	—	—
	15	—	—	—	—	—	—
	16	—	—	—	—	—	—
FR2 / \$0.40	1	1078	24	47	8.6	\$2.15	5.00
	2	1075	10	72	8.6	\$2.15	5.00
	3	925	8	68	8.7	\$1.85	4.27
	4	1125	8	23	11.2	\$2.25	4.03
	5	1125	8	62	10.5	\$2.25	4.28
	6	1125	10	45	10.0	\$2.25	4.52
	7	1125	5	33	11.2	\$2.25	4.03
	8	1125	27	51	15.1	\$2.25	2.98
	9	906	46	86	7.2	\$1.80	5.00
	10	1125	8	59	10.2	\$2.25	4.42
	11	1125	8	49	11.7	\$2.25	3.83
	12	1000	45	67	8.0	\$2.00	5.00
	13	1125	11	75	10.0	\$2.25	4.48
	14	1125	13	73	9.0	\$2.25	5.00
	15	1125	23	47	15.0	\$2.25	3.00
	16	1125	28	55	13.5	\$2.25	3.33
FR20 / \$0.40	1	1081	23	401	8.6	\$2.15	5.00
	2	1075	10	72	8.6	\$2.15	5.00
	3	1125	17	683	10.5	\$2.25	4.27
	4	1125	9	224	10.8	\$2.25	4.17
	5	775	16	712	6.2	\$1.55	5.00
	6	987	7	178	9.8	\$2.45	5.00
	7	1125	5	33	9.0	\$2.25	5.00
	8	1125	22	614	11.3	\$2.25	4.00
	9	706	4	467	4.0	\$1.00	5.00
	10	1000	11	444	8.0	\$2.00	5.00

Table 2
Continued

Condition	Participant	Total Approach	Total Observe	Total Avoid	Reinforcers per Minute	Earnings (USD)	Session Duration (mins)
	11	1100	11	513	8.8	\$2.20	5.00
	12	856	69	435	6.8	\$1.70	5.00
	13	862	9	683	6.8	\$1.70	5.00
	14	1125	5	576	10.5	\$2.25	4.28
	15	1125	15	212	12.9	\$2.25	3.50
	16	1125	12	212	11.3	\$2.25	4.00

the threat level displayed changed randomly (range 0 to 100) every 4 s, but changes in the *programmed* threat level still occurred.

Group and individual participant analyses focused on the effects of instructed threat on three dependent measures: (a) threat levels associated with AA transitions during 'Approach to Avoidance' and 'Avoidance to Approach,' (b) frequency of observing and (c) earnings. For each dependent measure, repeated-measures ANOVA with conditions and blocks were used as within-subject factors. For all tests, the criterion alpha level was set at $p < .05$ with Bonferroni correction when pairwise comparisons were performed ($.05/4$). Stability for each condition was assessed post-hoc at a group and individual participant level using earnings.

Results and Discussion

AA transitions. Figure 8 displays cycles of human approach-avoidance behavior when threat information was Available, Unavailable and Inaccurate; the top and middle rows show cumulative and total approach and avoidance responses over a 100-s time period. Available and unavailable threat information produced cyclical AA response patterns characterized by regular transitions and consistent bouts of approach and avoidance responding. In contrast, inaccurate information produced undifferentiated responding that appears under the control of displayed threat information, which varied randomly every 4 s. The bottom row of plots shows changes in the displayed threat, which could be observed during Accurate and Inaccurate conditions, and programmed threat levels. For Accurate and Inaccurate conditions, the cyclical AA response patterns are mirrored in the regular changes of the programmed threat level, which declined with

avoidance. By comparison, the high rate of avoidance in the Inaccurate condition drove down the programmed threat level.

Figure 9A and summary Table 3 present group mean threat levels associated with transitions from (left panel) 'Approach to Avoidance' and (right panel) 'Avoidance to Approach' for each experimental condition. Individual participant data for each condition appear in Figure 10A. For 'Approach to Avoidance', there was a significant condition effect ($F(2,28) = 6.98, p = .003$). Inaccurate condition transitions were found to occur at a significantly higher threat level ($M = 67.0, SD = 33.19$) than transitions in Available ($M = 45.0, SD = 25.01; p = .026$) and Unavailable ($M = 47.7, SD = 32.4; p = .042$) conditions. For 'Avoidance to Approach', there also was a significant condition effect ($F(2,28) = 8.96, p = .001$). Accurate condition transitions were found to occur at a significantly lower threat level ($M = 4.9, SD = 4.84$) than Inaccurate ($M = 39.1, SD = 34.2, p = .003$) and Unavailable ($M = 23.8, SD = 29.2; p = .05$) conditions. Individual participant data for each condition appearing in Figure 10A reflect these group findings.

Observing. Figure 9B presents group means for the frequency of Approach:Observe:Approach and Approach:Observe:Avoid patterns. It is important to note that the frequency of Approach:Observe:Avoid patterns highlights the frequency of AA cycles. No significant differences were found across conditions for Approach:Observe:Approach patterns ($F(2,28) = 2.11, p = .140$) or Approach:Observe:Avoid patterns ($F(2,28) = .335, p = .778$). Individual participant data for each condition appearing in Figure 10B support these group findings.

Earnings. Figure 11A shows earnings for individual participants and the group for all

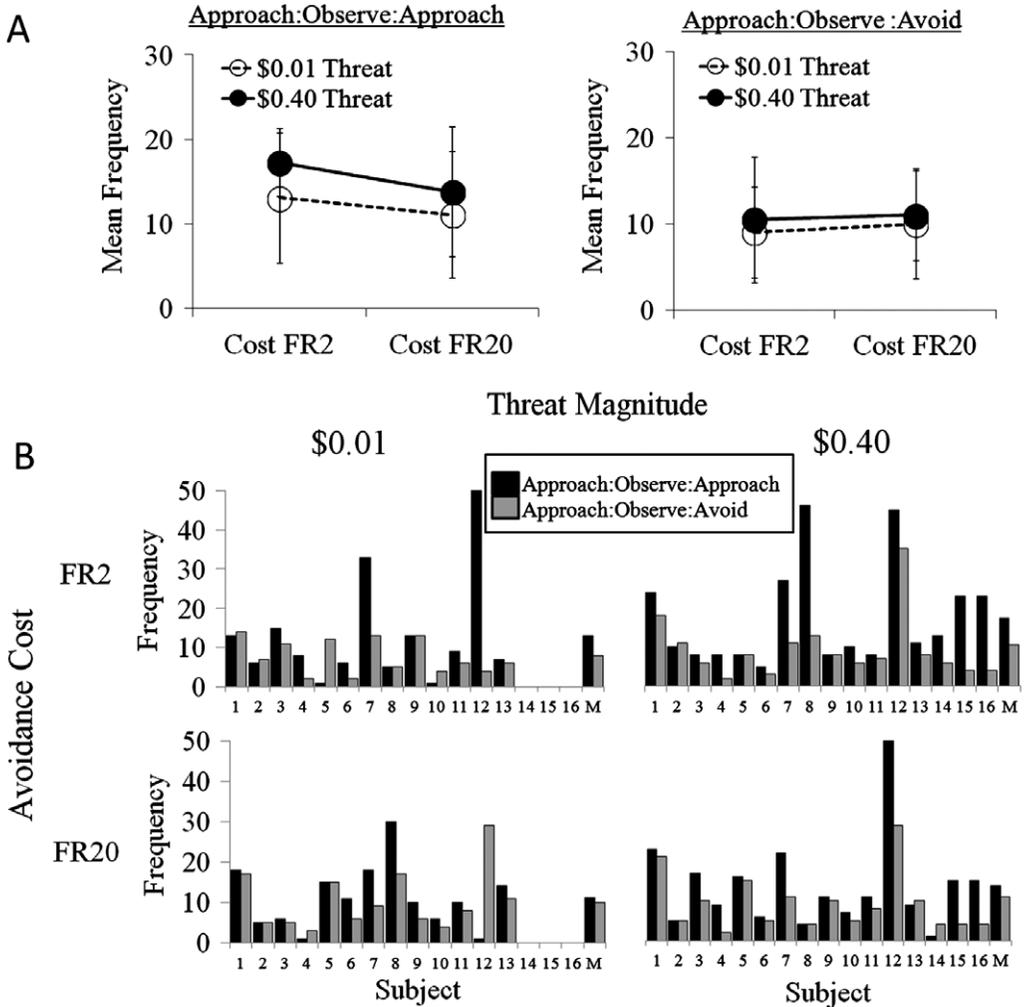


Fig. 6. Observing frequencies during Experiment 1. [A] Group mean frequency of engaging in approach responding, observing threat and returning to approach responding (left: Approach:Observe:Approach), and engaging in approach responding, observing threat and initiating avoidance responding (right: Approach:Observe:Avoid). No significant differences between conditions were found. (Bars represent 95% confidence intervals.) [B] Individual participant results for Approach:Observe:Approach (filled bars) and Approach:Observe:Avoid (grey bars) for each experimental condition. (M = group mean)

three blocks of Available, Unavailable and Inaccurate conditions. Analysis of earnings in block 3 revealed a significant condition effect ($F(2,28) = 8.81, p = .001$) in which earnings were higher in the Available condition ($M = \$1.53, SD = \1.41) compared to the Inaccurate ($M = -\$8.75, SD = \$9.75, p = .004$) but not the Unavailable condition ($M = -\$2.14, SD = \$7.80, p = .222$). The substantially lower earnings in Inaccurate and Unavailable conditions occurred because the *programmed* threat (not observable during these

conditions) reached threat level 98, triggering the loss-loss interval and substantial losses. However, increased earnings were observed in blocks 2 and 3 relative to block 1 for 100% (15/15) of participants in the Available condition, 87% (13/15) of participants for the Unavailable condition and 73% (11/15) of participants for the Inaccurate condition. The increased earnings observed in the Inaccurate condition stemmed from reductions in loss contacts across blocks. Figure 11B shows the distribution of participants as a function of the

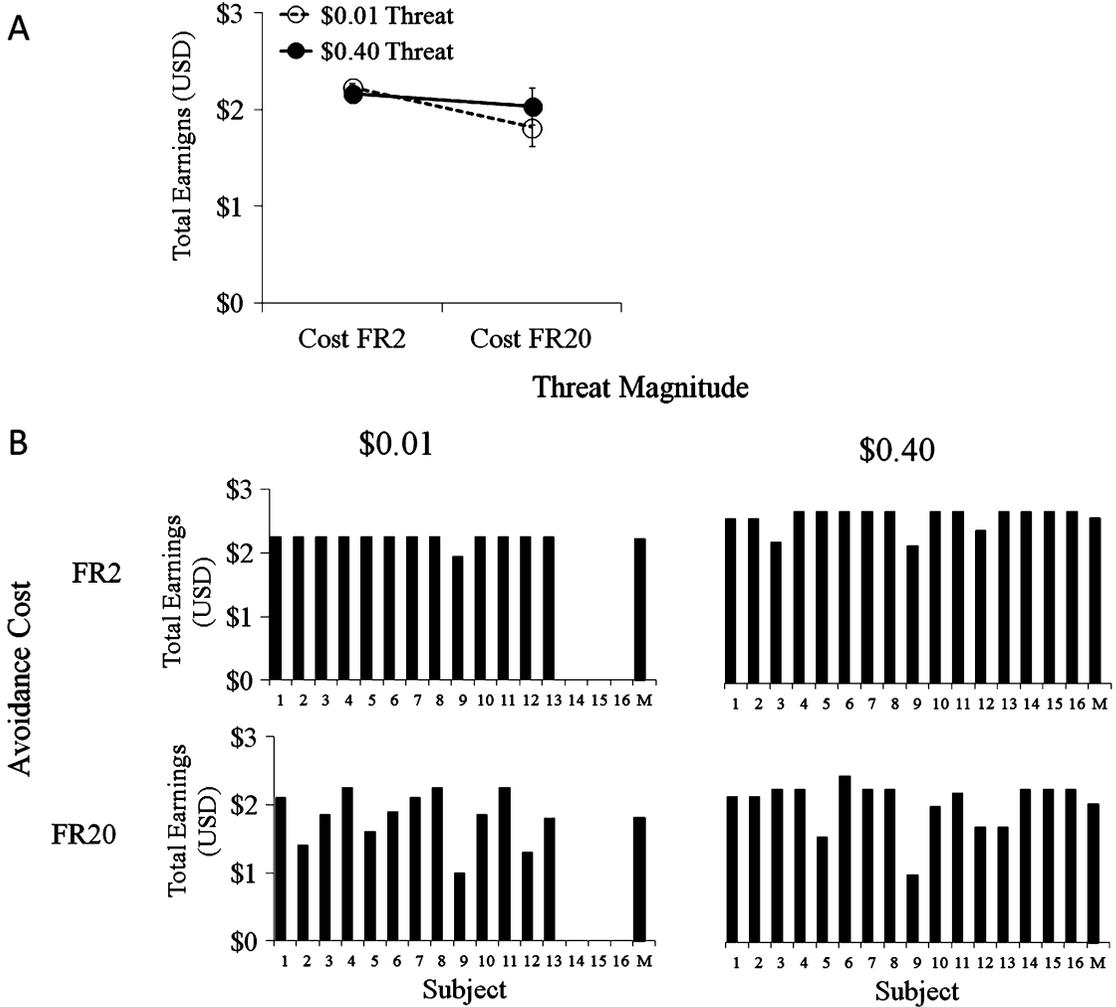


Fig. 7. Earnings during Experiment 1. [A] Group mean earnings showed a significant decline with increased avoidance cost (FR 2 to FR20) but not increased threat magnitude (\$0.01 to \$0.40). (Bars represent 95% confidence intervals.) [B] Individual participant results showed a marginal decline in earnings with increased avoidance cost, which can be accounted for by the increase in time needed to complete the FR20 schedule of avoidance. (M = group mean)

frequency of loss contacts for each block of the Inaccurate condition. There is a marked reduction in loss contacts from block 1 to 2. Group analysis of the frequency of loss contacts across blocks highlighted a significant decline ($F(2,28) = 5.69, p = .008$).

Stability analyses using changes in earnings for each condition showed fewer subjects met the stability criterion when threat information was Unavailable and Inaccurate, but mean earnings significantly increased across blocks for each condition suggesting more adaptive AA patterns were emerging with experience. When information was

Accurate 80% (12/15) of participants met the stability criterion and mean earnings significantly increased across blocks ($F(2,28) = 14.60, p < .001$), following a linear trend ($F(1,14) = 15.17, p = .002$). When information was Unavailable, 53% (8/15) of participants met the stability criterion and mean earnings significantly increased across blocks ($F(2,28) = 5.23, p = .008$), also showing a linear trend ($F(1,14) = 7.60, p = .025$). Finally, when information was Inaccurate only 40% (6/15) of participants met the stability criterion and mean earnings significantly increased across blocks ($F(2,28) = 7.58,$

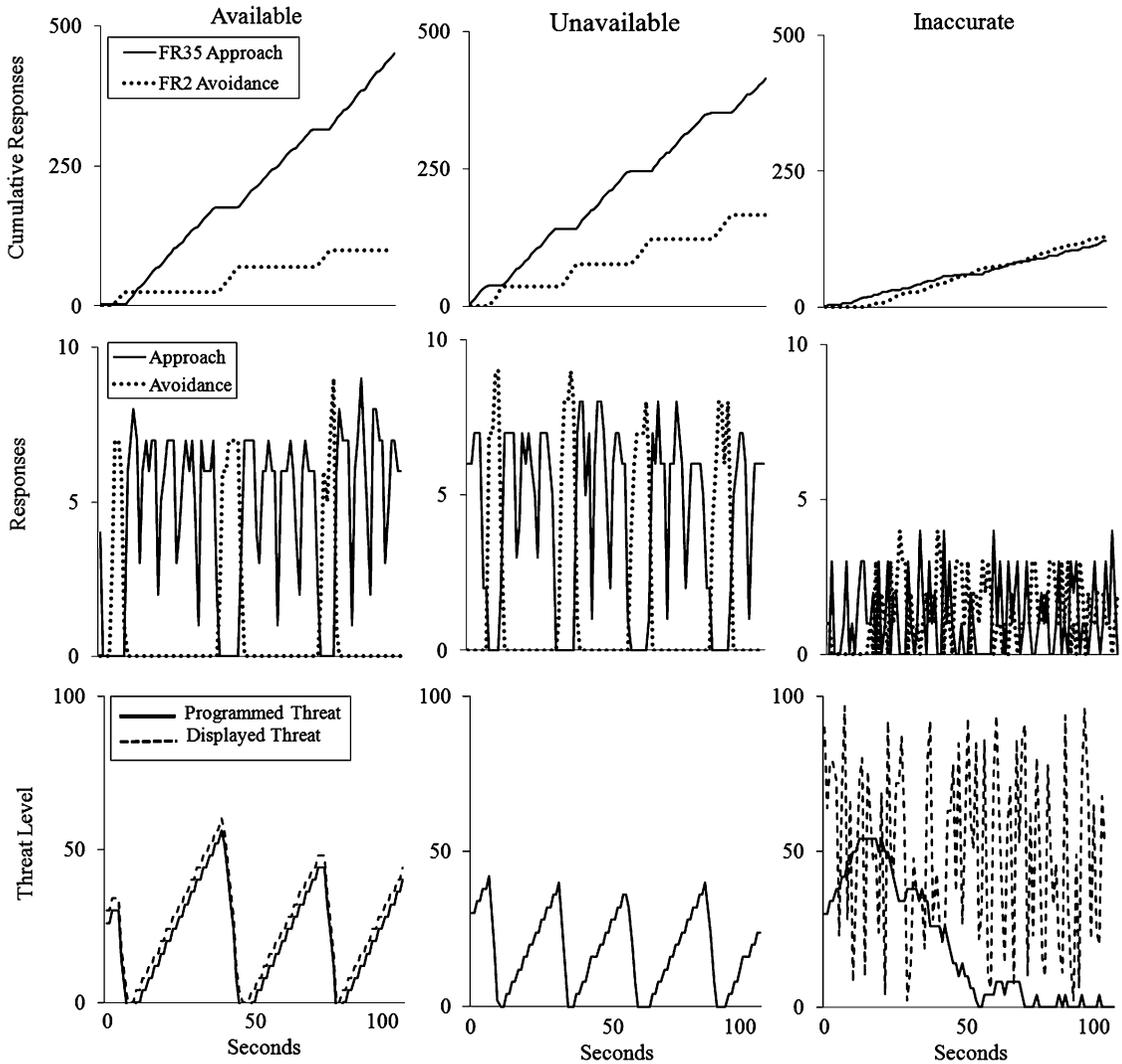


Fig. 8. Cycles of human approach-avoidance behavior during Experiment 2. Each column presents data from Available, Unavailable and Inaccurate threat conditions for one representative participant. Top and middle rows show cumulative and total approach and avoidance responses for a 100-s period. Available and Unavailable threat information produced alternating bouts of approach and avoidance responding. In contrast, Inaccurate information produced undifferentiated responding. The bottom row shows changes in displayed (observable) and programmed threat levels. The programmed threat level increased over time and decreased under FR2 avoidance.

$p = .002$), following a linear trend ($F(1,14) = 9.02$, $p = .009$).

General Discussion

The present experiments were designed to advance our understanding of how instructions about threat and avoidance impact control by competing appetitive and aversive contingencies over human AA behavior. Using a within-subjects design, two experiments were

conducted using a free-operant AA task designed to model appetitive-aversive competition and transitions present in naturalistic situations. During the AA task, approach responding was maintained on an FR schedule of reinforcement and pressing an observing button produced a rising threat meter that participants were told represented their chances of losing money; in fact, money loss *only* occurred when the threat level peaked. Through avoidance responding, the threat

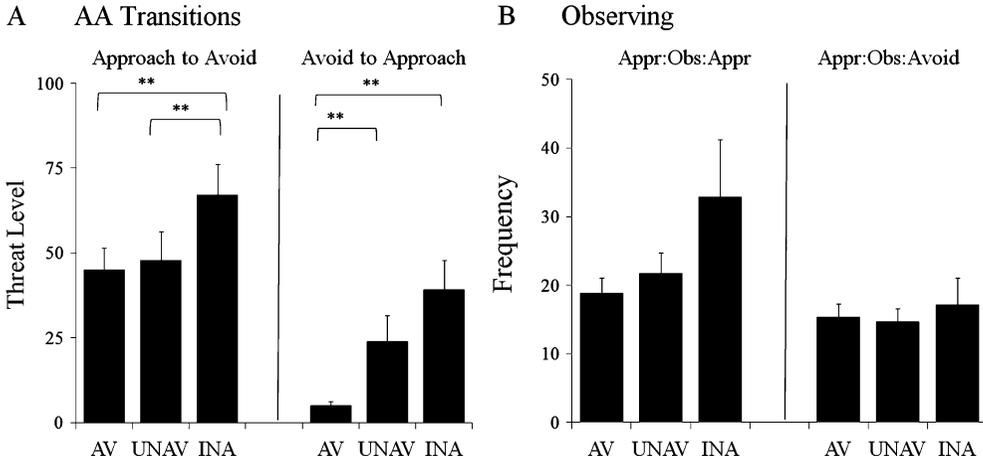


Fig. 9. Group AA transitions and observing frequencies during Experiment 2. [A] Group mean threat levels associated with transitions from (left panel) 'Approach to Avoidance' and (right panel) 'Avoidance to Approach.' Inaccurate condition transitions for 'Approach to Avoidance' were significantly higher than transitions for Available and Unavailable conditions. Unavailable and Inaccurate transitions for 'Avoid to Approach' were significantly higher than transitions for Available. [B] Group mean frequency of engaging in approach responding, observing threat and returning to approach responding (left panel: Appr:Obs:Appr), and engaging in approach responding, observing threat and initiating avoidance responding (right panel: Appr:Obs:Avoid). No significant differences were found among conditions. (Bars represent 95% confidence intervals. AV = Available, UNAV = Unavailable, INA = Inaccurate; Appr = Approach, Obs = Observe; $**p < .05$, Bonferroni corrected)

level displayed could be lowered. Both experiments showed instructed threat and avoidance maintained AA behavior. Experiment 1 revealed increasing avoidance cost, but not threat magnitude, shifted AA transitions to higher threat levels and increased anxiety ratings, but did not influence frequency of AA transitions. Experiment 2 revealed when threat level information was available or absent earnings were high, but earnings decreased when inaccurate threat information was incompatible with contingencies.

Our findings make several contributions to research on human AA, as well as inform operant research on instructional control. Instructed threat and avoidance maintained human AA behavior in ways consistent with results reported in prior human and nonhuman AA studies using aversive contingencies (Amemori & Graybiel, 2012; Aupperle et al., 2011, 2015; Bach et al., 2014; Lippa et al., 1978; Rowlett et al., 2006; Schlund et al., 2016; Sierra-Mercado et al., 2015; Vogel et al., 1971). Our instructions successfully established higher levels on a threat meter as more aversive than lower levels, and higher threat levels generated significantly more reported anxiety than lower threat levels. Moreover, when avoidance cost was increased from FR2 to

FR20 and transitions from approach to avoidance increased to higher threat levels, there was a corresponding increase in anxiety ratings. Despite individual differences, high threat levels were associated with switching from approach to avoidance and avoidance responding was maintained until the displayed threat level was reduced. When threat information was not displayed, AA behavior patterns more closely resembled conditions in which threat information was accurate than inaccurate. Importantly, when threat information was inaccurate, AA behavior patterns were initially controlled by displayed threat as evidenced by the high frequency of loss contacts and low earnings. However, across blocks there were significant reductions in loss contact and increased earnings consistent with a shift away from control by displayed threat to programmed threat, modeling well documented shifts from instructional to contingency control when the types of control are incompatible (Baron & Galizio, 1983; Galizio, 1979).

Results provided some support for our assumption that control by instructed threat during AA might benefit from instructions about avoidance. Threat reduction appeared to function as a negative reinforcer for avoidance. The absence of money loss with threat

Table 3
Performance summaries for experiment 2.

Condition	Participant	Total Approach	Total Observe	Total Avoid	Reinforcers /Minute of	Frequency Loss	Earnings (USD)	Session Duration(mins)
Available	1	721	22	306	4	0	\$1.40	5
	2	1177	12	304	7	0	\$2.31	5
	3	830	22	302	5	0	\$1.61	5
	4	949	33	311	5	0	\$1.89	5
	5	867	8	280	5	9	-\$0.21	5
	6	714	25	278	4	20	-\$2.80	5
	7	1217	10	323	7	0	\$2.38	5
	8	912	24	326	5	0	\$1.82	5
	9	982	35	319	6	0	\$1.96	5
	10	595	22	295	3	0	\$1.19	5
	11	1340	11	313	8	0	\$2.66	5
	12	1050	24	285	6	0	\$2.10	5
	13	813	7	309	5	0	\$1.61	5
	14	1575	17	296	9	0	\$3.15	5
	Unavailable	15	965	10	301	6	0	\$1.89
1		665	24	412	4	0	\$1.33	5
2		1150	36	296	7	0	\$2.24	5
3		805	15	264	5	5	\$0.56	5
4		871	29	442	5	0	\$1.68	5
5		758	16	257	4	27	-\$4.20	5
6		660	49	280	4	55	-\$7.98	5
7		1067	8	403	6	0	\$2.10	5
8		862	20	375	5	0	\$1.68	5
9		687	19	643	4	0	\$1.33	5
10		336	13	4	2	133	-\$27.30	5
11		1155	18	501	7	0	\$2.31	5
12		933	39	226	5	28	-\$4.06	5
13		643	10	218	4	36	-\$6.51	5
14		1509	19	396	9	2	\$2.59	5
Inaccurate	15	1088	11	355	6	0	\$2.17	5
	1	695	10	44	4	115	-\$23.03	5
	2	700	51	345	4	0	\$1.40	5
	3	636	25	223	4	46	-\$8.40	5
	4	560	22	455	3	0	\$1.12	5
	5	578	15	254	3	34	-\$6.02	5
	6	640	63	238	4	41	-\$7.35	5
	7	769	4	0	4	132	-\$26.46	5
	8	906	14	320	5	4	\$0.91	5
	9	637	19	407	4	0	\$1.26	5
	10	151	22	102	1	98	-\$20.51	5
	11	331	136	304	2	24	-\$4.41	5
	12	705	36	257	4	29	-\$4.69	5
	13	630	13	268	4	18	-\$2.52	5
	14	673	34	85	4	114	-\$22.82	5
15	94	28	289	1	46	-\$9.73	5	

reduction may have also negatively reinforced following instructions about threat because of the compatibility between instructions and contingencies (Baron & Galizio, 1983; Galizio, 1979). Also, it is important to note that the regular AA cycles were not controlled by instructions. Although participants were informed about the function of buttons and threat meter increases, no instructions were provided about how or when to respond. Most likely the AA

cycles reflect temporal control by the threat meter, which increased at a constant rate and visibly decreased during avoidance. Similar levels of temporal control over avoidance behavior have been observed in prior nonhuman and human studies (Anger, 1963; Baron & Galizio, 1976; Himeline, 1970; Himeline & Herrnstein, 1970; Sidman, 1962a,b).

Experiment 1 was designed to examine the effects of different threat magnitudes and

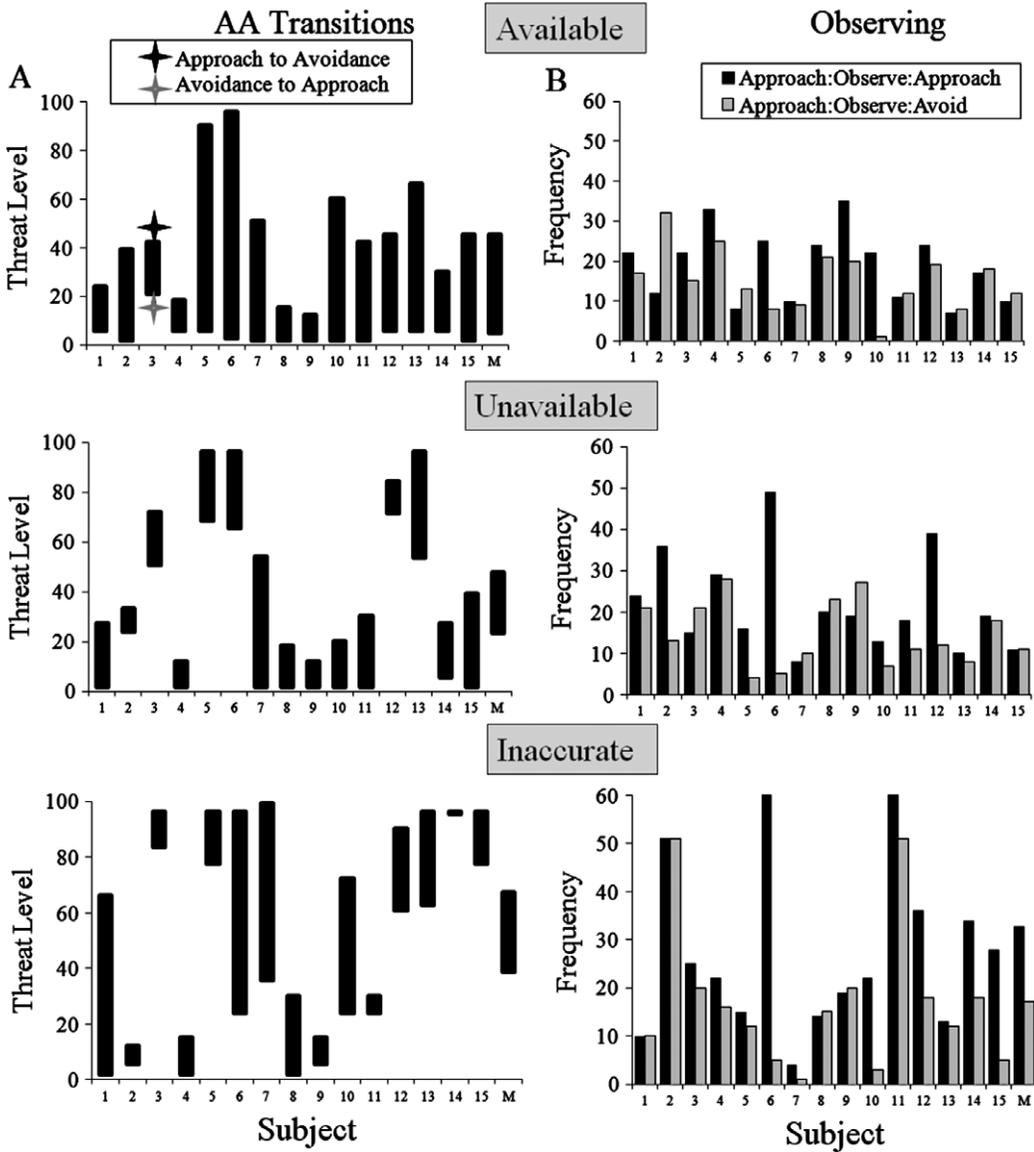


Fig. 10. Individual participant AA transitions and observing frequencies during Experiment 2. [A] AA transition points that reflect threat levels associated with >50% probability of switching from 'Approach to Avoidance' (top of bar) and >50% probability of switching from 'Avoidance to Approach' (bottom of bar) by condition. [B] Individual participant observing frequencies for Approach:Observe:Approach (filled bars) and Approach:Observe:Avoid (grey bars) by condition. (M = group mean)

avoidance costs on AA behavior patterns. Results indicated increasing the fixed ratio requirement for avoidance increased AA transitions to a higher threat level, which was inconsistent with our idea that greater avoidance cost would increase aversive control and push AA transitions to a lower threat level. Numerous behavior analytic studies have

demonstrated that response cost in the form of increased physical effort or loss of positive reinforcers is capable of reducing escape-maintained problem behavior (Horner & Day, 1991; Van Camp, Vollmer & Daniel, 2001; Worsdell, Iwata, Hanley, Thompson & Kahng, 2000). Our findings did not suggest that avoidance responding per se was reduced but

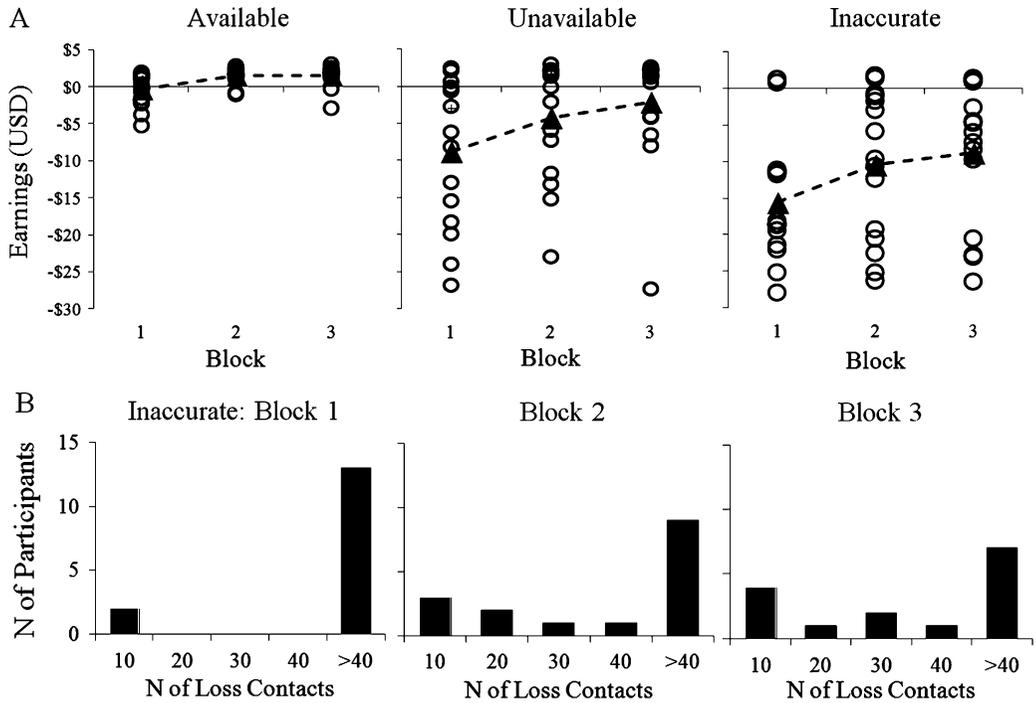


Fig. 11. Earnings and frequency of loss contacts during Experiment 2. [A] Individual participant (open circles) and group mean (filled rectangles) earnings plotted for Available, Unavailable and Inaccurate threat conditions for three blocks. For block 3, earnings were significantly greater when threat information was available compared to when threat information was inaccurate. [B] Distribution of participants as a function of the frequency of loss contacts (bin size = 10) for each block of the Inaccurate condition. Results show a marked reduction in contacts from block 1 to 2.

instead AA transitions began and ended at higher threat levels. Moreover, although increased cost was associated with a significant decrease in earnings, the decrease was negligible and predictable because more time was needed to complete the larger FR20 avoidance. It is plausible to suggest that increased avoidance cost may have resulted in a devaluation of the negative reinforcer, which also occurs with positive reinforcers (Friman & Poling, 1995; Hartmann, Hager, Tobler & Kaiser, 2013; Nishiyama, 2014). With regard to threat magnitude, results were inconsistent with our prediction as findings showed increased money loss did not increase aversive control and push AA transitions to a lower threat level. This outcome may reflect that loss per se was more aversive under these conditions than the actual loss magnitude or, alternatively, loss magnitude exerts little differential control when avoidance is consistently successful.

In applied behavior analysis, the clinical significance of understanding the competition between appetitive and aversive contingencies

in escape-maintained problem behavior is a primary focus of concern (Bouxein, Roane & Harper, 2011; Kodak, Lerman, Volkert & Troscclair, 2007; Payne & Dozier, 2013). In such cases, clinicians determine problem behavior has an escape function, such as aggressive responding to demands, maintained by negative reinforcement. Treatment can involve delivery of a highly preferred reinforcer contingent on compliance, such that behavior contacts both the aversive stimulus (demand) along with the positive reinforcer. When the positive reinforcer exerts greater control than the negative reinforcer, results show a decline in the frequency of escape responding (or avoidance) and an increase in compliance with demands (approach). These clinical situations parallel the competition between appetitive and aversive contingencies in AA conflict and also involve a choice between concurrently available but different forms of reinforcement.

Future investigations are needed to address a number of potential limitations that may

limit generalization of findings. The duration of each condition was brief and the number of exposures to each condition should be increased to facilitate stable responding. The failure of threat magnitude to affect AA behavior patterns could stem from failure to use a money-loss amount of sufficient aversive magnitude. Electric shock is more commonly used in studies on fear learning and avoidance, so additional research contrasting money loss with shock would be informative. Currently, it remains unclear what variable(s) contributed to the between-subject variability observed. Further research addressing the interplay among individual differences variables in AA, such as anxiety (Aupperle *et al.*, 2011), depression (Trew, 2011) and genetic factors (Richter *et al.*, 2014), may provide new insights.

In summary, our findings build on prior nonhuman and human AA research by highlighting how instructed threat and avoidance can impact human AA behavior and self-reported anxiety. Moreover, the present investigation found that increasing avoidance cost weakened control by instructed threat, and inaccurate threat information can exert disproportionate control over human AA behavior. Why research on aversive control in operant psychology has not increased remains puzzling (Baron, 1991; Critchfield & Rasmussen, 2007), particularly given that excessive avoidance accompanied by fear, anxiety and intolerance of threat are all core diagnostic features of anxiety, trauma and stress related disorders (American Psychiatric Association, 2013; Craske, Rauch, Ursano, Prenoveau, Pine, & Zinbargh, 2009; Dymond & Roche, 2009). The growth in basic and translational behavioral and neurophysiological research on avoidance and AA (Le Doux, Moscarello, Sears, & Campese, 2016; Servatius, 2016) presents behavior analysis with a pathway to interdisciplinary research that it cannot afford to avoid.

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