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"Watch out!": Effects of instructed threat and avoidance on human free-operant approach-avoidance behavior

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Abstract

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 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, 1938; 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, Guitart-Masip, Packard, Miró, Falip, Fuentemilla & Dolan, 2014; Schlund, Siegle, Ladouceur, Silk, Cataldo, Forbes, Dahl, & Ryan, 2010a; Schlund & Cataldo, 2010b; Schlund, Magee & Hudgins, 2011; Schlund, Brewer, Magee, Richman, Solomon, Ludlum & Dymond, 2016; Sierra-Mercado, Deckersbach, Arulpragasam, Chou, Rodman, Duffy, McDonald, Eckhardt, Corse, Kaur, Eskandar & Dougherty, 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. (2014)

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 (Lindstrom & 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 Krypotos, 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; Krypotos, 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., 2014), 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; Hineline, 1970;

Hineline & Hernstein, 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.

Insert Figure 1 about here

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 sixteen adults (M_{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.

Procedure

Conditions

A within-subjects 2x2 factorial design incorporated two levels each of threat magnitude ($0.01 loss, $0.40 loss) and avoidance cost (FR2, FR20), creating four experimental conditions. Each condition ended after either 5 minutes or $2.25 was earned, whichever came first. All four experimental conditions were presented randomized in a block. A total of two blocks were completed by each participant. Results presented for each condition are based upon the second block, unless otherwise noted.

Instructions

At the start of each experimental condition, participants sat facing the computer monitor and the experimenter read aloud the following instructions:

> “Your task is to use buttons 1-3 to earn money. The task lasts about 5 minutes. It begins when you view:
>
> 1=Money 2=Switch ---

> Now you have a choice. If you press button #1 (Money button) you will earn 10 cents every so often. When you earn money, you will see a message on the screen. Located behind “----“ is information about the level of threat to your money. The threat is that you will lose (1 or 40) cents. When you lose money, a message will appear on the screen telling you.
>
> You can use button #2 to 'switch' the view to see the current threat level. After pressing #2 you will see the following:
>
> 1 --- 3=Reduce
> Threat Level = _XX_
> 0=Very Low 50=Moderate 100=Very High
>
> The scale shows that when XX threat level is at 0 you can't lose money, 50 is midway so loss is more likely and at 100 you will lose money. During the task, the threat level will increase. The good news is that the level can be 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 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 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 the threat level displayed represented how likely they could lose money. Unbeknownst to subjects, 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.

Insert Figure 2 about here

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 2x2 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 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.

Insert Table 1 and Figure 3 about here

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 subject. 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.

Insert Figure 4 about here

Group and individual subject results suggest that increasing from FR2 avoidance to FR20 avoidance weakened control by instructed threat, but increasing the threat magnitude from $0.01 to $0.40 did not. Figure 5 and summary Table 2 present group mean and individual subject threat levels that were associated with switching from 'Approach to Avoidance' and 'Avoidance to Approach'. For 'Approach to Avoidance' transitions, increased FR avoidance cost resulted in an increase in the threat level at which transitions occurred. We found a significant main effect of avoidance cost ($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 subject level.

Insert Figure 5 and Table 2 about here

Observing

Overall, group and individual subject 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 $0.40. Figure 6 presents group and individual subject observing frequencies for Approach:Observe:Approach and Approach:Observe:Avoid. It is important to note the frequency of Approach:Observe:Avoid patterns also highlights the frequency of AA cycles. Group analyses of the frequency of Approach:Observe:Approach patterns showed no significant main effect of avoidance cost **(**$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 subject analysis.

Insert Figure 6 about here

Earnings

Figure 7 shows group mean and individual subject 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* = 0.0125). In the FR2 avoidance / $0.40 loss condition 75% (12/16) of subjects 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 subjects met the stability criterion and mean earnings did not significantly increase between blocks (*t*(12) = 2.30, *p* = 0.04). In the FR20 avoidance / $0.40 loss condition 69% (11/16) of subjects met the stability criterion and mean earnings did not significantly change between blocks (*t*(15) = 0.07, *p* = .94).. Finally, in the FR20 avoidance /

$0.01 loss condition 85% (11/13) of subjects met the stability criterion and mean earnings did not significantly change between blocks ($t(12) = 1.87$, $p = 0.09$).

Insert Figure 7 about here

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 otherwise punished, responding will shift from control by instructions to 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 ($M_{age} = 28.9$, $SD = 4.4$, 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.

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 minutes. 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 2 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 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 subject 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 subject 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 to low levels.

Insert Figure 8 about here

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 subject 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 subject data for each condition appearing in Figure 10A reflect these group findings.

Observing

Figure 9B presents group means of 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 subject data for each condition appearing in Figure 10B support these group findings.

Insert Figures 9 and 10 and Table 3 about here

Earnings

Figure 11A shows earnings for individual subjects and the group for all 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 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 ($F(2,28) = 5.69$, $p = .008$).

Insert Figure 11 about here

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 subjects met the stability criterion and mean earnings significantly increased across blocks ($F(2,28) = 14.60$, $p < 0.001$), following a linear trend ($F(1,14) = 15.17$, $p = .002$). When information was Unavailable, 53% (8/15) of subjects met the stability criterion and mean earnings significantly increased across blocks ($F(2,28) = 5.23$, $p = 0.008$), also showing a linear trend ($F(1,14) = 7.60$, $p = 0.025$). Finally, when information was Inaccurate only 40% (6/15) of subjects met the stability criterion and mean earnings significantly increased across blocks ($F(2,28) = 7.58$, $p = 0.002$), following a linear trend ($F(1,14) = 9.02$, $p = 0.009$).

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 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., 2014; 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 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; Hineline, 1970; Hineline & Hernstein, 1970; Sidman, 1962a,b).

Experiment 1 was designed to examine the effects of different threat magnitudes and 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 are 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 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 (Bouxsein, Roane & Harper, 2011; Kodak, Lerman, Volkert & Trosclair, 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 the behavior analysis with a pathway to interdisciplinary research that it cannot afford to avoid.

Conflict of interest

All authors have no conflict of interest.

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References

References

American Psychiatric Association (2013). *Diagnostic and Statistical Manual of Mental Disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Amemori, K. I., & Graybiel, A. M. (2012). Localized microstimulation of primate pregenual cingulate cortex induces negative decision-making. *Nature Neuroscience, 15*, 776-785. doi:10.1038/nn.3088

Anger, D. (1963). The role of temporal discriminations in the reinforcement of Sidman avoidance behavior. *Journal of the Experimental Analysis of Behavior, 6*, 477-506. doi: 10.1901/jeab.1963.6-s477

Aupperle R. L., & Martin, P. P. (2010). Neural systems underlying approach and avoidance in anxiety disorders. *Dialogues in Clinical Neuroscience*, *12*, 517-531.

Aupperle, R. L., Sullivan, S., Melrose, A. J., Paulus, M. P., & Stein, M. B. (2011). A reverse translational approach to quantify approach-avoidance conflict in humans. *Behavioural Brain Research*, *225*, 455-463. doi: 10.1016/j.bbr.2011.08.003

Aupperle, R. L., Melrose, A. J., Francisco, A., Paulus, M. P., & Stein, M. B. (2015). Neural substrates of approach-avoidance conflict decision-making. *Human Brain Mapping, 36*, 449-462. doi: 10.1002/hbm.22639

Bach, D. R., Guitart-Masip, M., Packard, P. A., Miró, J., Falip, M., Fuentemilla, L., & Dolan, R. J. (2014). Human hippocampus arbitrates approach-avoidance conflict. *Current Biology*, *24*, 541-547. doi: 10.1016/j.cub.2014.01.046

Baron, A. (1991). Avoidance and punishment. In I. H. Iversen & K. A. Lattal (Eds.), *Experimental analysis of behavior, Part 1* (pp. 173–217). Amsterdam: Elsevier.

Baron, A., & Galizio, M. (1976). Clock control of human performance on avoidance and fixed-interval schedules. *Journal of the Experimental Analysis of Behavior, 26*, 165-180. doi: 10.1901/jeab.1976.26-165

Baron, A., & Galizio, M. (1983). Instructional control of human operant behavior. *Psychological Record, 33,* 495–520.

Botvinick, M. M. (2007). Conflict monitoring and decision making: Reconciling two perspectives on anterior cingulate function. *Cognitive, Affective, & Behavioral Neuroscience*, *7,* 356-366. doi: 10.3758/CABN.7.4.356

Bouxsein, K. J., Roane, H. S., & Harper, T. (2011). Evaluating the separate and combined effects of positive and negative reinforcement on task compliance. *Journal of Applied Behavior Analysis*, *44*, 175-179. doi: 10.1901/jaba.2011.44-175

Cameron, G., Roche, B., Schlund, M.W., & Dymond, S. (2016). Learned, instructed and observed pathways to fear and avoidance. *Journal of Behavior Therapy and Experimental Psychiatry, 50,* 106-112. doi: 10.1016/j.jbtep.2015.06.003

Craske, M. G., Rauch, S. L., Ursano, R., Prenoveau, J., Pine, D. S., & Zinbargh, R. E. (2009). What is an anxiety disorder? *Depression and Anxiety*, *26,* 1066–1085.

Critchfield, T. S. (2011). Translational contributions of the experimental analysis of behavior. *The Behavior Analyst*, *34*, 3–17. PMCID: PMC3089409

Critchfield, T. S., & Rasmussen, E. R. (2007). It's aversive to have an incomplete science of behavior. *Mexican Journal of Behavior Analysis*, *33*, 1–6.

Dymond, S., & Roche, B. (2009). A contemporary behavior analysis of anxiety and avoidance. *The Behavior Analyst*, *32*, 7-28. PMCID: PMC2686994

Dymond, S., Schlund, M. W., Roche, B., De Houwer, J., & Freegard, G. P. (2012). Safe from harm: Learned, instructed, and symbolic generalization pathways of human threat-avoidance. *PLoS ONE, 7,* e47539. doi: 10.1371/journal.pone.047539

Elliot, A. J. (2008). *Handbook of approach and avoidance motivation.* New York: Taylor & Francis.

Elliot, A. J., & Church, M. A. (1997). A hierarchical model of approach and avoidance achievement motivation. *Journal of Personality and Social Psychology*, *72,* 218-232. doi: 10.1037/0022-3514.72.1.218

Estes, W. K., & Skinner, B. F. (1941). Some quantitative properties of anxiety. *Journal of Experimental Psychology*, *29*, 390-400. doi: 10.1037/h0062283

Freud, S. (1924). Neurosis and Psychosis. In J. Strachey (Ed.), *The standard edition of the complete psychological works of Sigmund Freud* (1964), Vol. 19, 149. London: Vintage Classics.

Friman, P. C., & Poling, A. (1995). Making life easier with effort: Basic findings and applied research on response effort. *Journal of Applied Behavior Analysis*, *28*, 583-590. doi: 10.1901/jaba.1995.28-583

Galizio, M. (1979). Contingency-shaped and rule-governed behavior: Instructional control of human loss avoidance. *Journal of the Experimental Analysis of Behavior*, *3*, 53-70. doi: 10.1901/jeab.1979.31-53

Gray, J. A. (1985). Issues in the neuropsychology of anxiety. In A.H. Tuma & J. Maser (Eds). *Anxiety and the anxiety disorders* (pp.5-25). Hillsdale, NJ: Erlbaum.

Gray, J. A., & McNaughton N. (1996). The neuropsychology of anxiety: reprise. In R. A. Dienstbier and D.A., Hope (Eds.), *Perspectives in anxiety, panic, and fear* (Vol. 43) (pp. 61-134). Lincoln, NE: University of Nebraska Press.

Hartmann, M. N., Hager, O. M., Tobler, P. N., & Kaiser, S. (2013). Parabolic discounting of monetary rewards by physical effort. *Behavioural Processes*, *100*, 192-196. doi: 10.1016/j.beproc.2013.09.014

Hineline, P. N. (1970). Negative reinforcement without shock reduction. *Journal of the Experimental Analysis of Behavior*, *14*, 259-268. doi: 10.1901/jeab.1970.14-259

Hineline, P. N., & Herrnstein, R. J. (1970). Timing in free-operant and discrete-trial avoidance. *Journal of the Experimental Analysis of Behavior*, *13*, 113-126. doi: 10.1901/jeab.1970.13-113

Horner, R. H., & Day, H. M. (1991). The effects of response efficiency on functionally equivalent competing behaviors. *Journal of Applied Behavior Analysis*, *24*, 719-732. doi: 10.1901/jaba.1991.24-719

Kodak, T., Lerman, D. C., Volkert, V. M., & Trosclair, N. (2007). Further examination of factors that influence preference for positive versus negative reinforcement. *Journal of Applied Behavior Analysis*, *40*, 25-44. doi: 10.1901/jaba.2007.151-05

Krypotos, A.-M., Effting, M., Arnaudova, I., Kindt, M., & Beckers, T. (2014). Avoided by association: Acquisition, extinction, and renewal of avoidance tendencies towards conditioned fear stimuli. *Clinical Psychological Science, 2*, 336-343.

Krypotos, A.-M., Arnaudova, I., Effting, M., Kindt, M., & Beckers, T. (2015). Effects of approach-avoidance training on the extinction and return of fear responses. *PloS One, 10,* e0131581. doi: 10.1371/journal.pone.0131581

Lang, P. J. (1995). The emotion probe: Studies of motivation and attention. *American Psychologist*, *50,* 372. doi: 10.1037/0003-066X.50.5.372

Lang, P. J., & Bradley, M. M. (2008). Cortex-reflex connections appetitive and defensive motivation is the substrate of emotion. In A. J. Elliot (Ed.) *Handbook of approach and avoidance motivation* (pp. 51-66); New York, NY: Psychology Press

Larsen R. J., & Augustine A. A. (2008). Basic personality dispositions related to approach and avoidance: Extraversion/neuroticism, BAS/BIS, and positive/negative affectivity. In A.J. Elliot (Ed.) *Handbook of approach and avoidance motivation* (pp. 151-164); New York, NY: Psychology Press.

Le Doux, J. E., Moscarello, J., Sears, R., & Campese, V. (2016). The birth, death and resurrection of avoidance: A reconceptualization of a troubled paradigm. *Molecular Psychiatry,* 00, 1–13. doi:10.1038/mp.2016.166

Lewon, M., & Hayes, L. J. (2014). Toward an analysis of emotions as products of motivating operations. *The Psychological Record*, *64*, 813-825. doi: 10.1007/s40732-014-0046-7

Lindström, B., & Olsson, A. (2015). Mechanisms of social avoidance learning can explain the emergence of adaptive and arbitrary behavioral traditions in humans. *Journal of Experimental Psychology: General*, *144,* 688-703. doi: 10.1037/xge0000071

Lippa, A. S., Klepner, C. A., Yunger, L., Sano, M. C., Smith, W. V., & Beer, B. (1978). Relationship between benzodiazepine receptors and experimental anxiety in rats. *Pharmacology Biochemistry and Behavior*, *9,* 853-856. doi: 10.1016/0091-3057(78)90368-4

Nishiyama, R. (2014). Response effort discounts the subjective value of rewards. *Behavioural Processes*, *107*, 175-177. doi: 10.116/j.beproc.2014.08.002

Olsson, A., & Phelps, E. A. (2007). Social learning of fear. *Nature Neuroscience, 10,* 1095–1102. doi:10.1038/nn1968

Payne, S. W., & Dozier, C. L. (2013). Positive reinforcement as treatment for problem behavior maintained by negative reinforcement. *Journal of Applied Behavior Analysis*, *46*, 699-703. doi: 10.1002/jaba.54

Raes, A. K., De Houwer, J., De Schryver, M., Brass, M., & Kalisch, R. (2014). Do CS-US pairings actually matter? A within-subject comparison of instructed fear conditioning with and without actual CS-US pairings. *PLoS One*, *9*, e84888. doi: 10.1371/journal.pone.0084888

Rachman, S. (1977). The conditioning theory of fear acquisition: A critical examination. *Behaviour Research and Therapy, 15*, 375-387. doi: 10.1016/0005-7967(77)90041-9

Rescorla, R. A., & LoLordo, V. M. (1965). Inhibition of avoidance behavior. *Journal of Comparative and Physiological Psychology, 59*, 406–412. doi: 10.1037/h0022060

Richter, A., Guitart-Masip, M., Barman, A., Libeau, C., Behnisch, G., Czerney, S., Schanze, D., Assman, A., Klein, M., Duzel, E., Zenker, M., Seidenbecher, C., & Schott, B. H. (2014). Valenced action/inhibition learning in humans is modulated by a genetic variant linked to dopamine D2 receptor expression. *Frontiers in Systems Neuroscience, 8*, 140. doi: 10.3389/fnsys.2014.00140

Rowlett, J. K., Lelas, S., Tornatzky, W., & Licata, S. C. (2006). Anti-conflict effects of benzodiazepines in rhesus monkeys: Relationship with therapeutic doses in humans and role of GABAA receptors. *Psychopharmacology, 184*, 201-211. doi: 10.1007/s00213-005-0228-8

Schlund, M. W., Siegle, G. J., Ladouceur, C. D., Silk, J. S., Cataldo, M. F., Forbes, E. E., Dahl, R. E., & Ryan, N. D. (2010a). Nothing to fear? Neural systems supporting avoidance behavior in healthy youths. *Neuroimage*, *52*, 710-719. doi: 10.1016/j.neuroimage.2010.04.244

Schlund, M. W., & Cataldo, M. F. (2010b). Amygdala involvement in human avoidance, escape and approach behavior. *Neuroimage*, *53*, 769-776. doi: 10.1016/j.neuroimage.2010.06.058

Schlund, M. W., Magee, S., & Hudgins, C. D. (2011). Human avoidance and approach learning: Evidence for overlapping neural systems and experiential avoidance modulation of avoidance neurocircuitry. *Behavioural Brain Research*, *225*, 437-448. doi: 10.1016/j.bbr.211.07.054

Schlund, M. W., Brewer, A. T., Richman, D. M., Magee, S. K., & Dymond, S. (2015). Not so bad: Avoidance and aversive discounting modulate threat appraisal in anterior cingulate and medial prefrontal cortex. *Frontiers in Behavioral Neuroscience*, *9*, 142. doi: 10.3389/fnbeh.2015.00142

Schlund, M. W., Brewer, A. T., Magee, S. K., Richman, D. M., Solomon, S., Ludlum, M., & Dymond, S. (2016). The tipping point: Value differences and parallel dorsal-ventral frontal circuits gating human approach-avoidance behavior. *NeuroImage*, *136*, 94-105. doi: 10.1016/j.neuroimage.2016.04.070

Sierra-Mercado, D., Deckersbach, T., Arulpragasam, A. R., Chou, T., Rodman, A. M., Duffy, A., McDonald, E. J., Eckhardt, C. A., Corse, A. K., Kaur, N., Eskandar, E. N., & Dougherty, D. D. (2015). Decision making in avoidance–reward conflict: A paradigm for non-human primates and humans. *Brain Structure and Function*, *220*, 2509-2517. doi: 10.1007/s00429-014-0796-7

Servatius, R. J. (2016). Editorial: Avoidance: From basic science to psychopathology. *Frontiers in Behavioral Neuroscience,10*, 15. doi: 10.3389/fnbeh.2016.00015

Sidman, M. (1962a). An adjusting avoidance schedule. *Journal of the Experimental Analysis of Behavior*, *5*, 271-277. doi: 10.1901/jeab.1962.5-271

Sidman, M. (1962b). Reduction of shock frequency as reinforcement for avoidance behavior. *Journal of the Experimental Analysis of Behavior*, *5*, 247-257. doi: 10.1901/jeab.1962.5-247

Trew, J. L. (2011). Exploring the roles of approach and avoidance in depression: An integrative model. *Clinical Psychology Review*, *31*, 1156-1168. doi: 10.1016/j.cpr.2011.07.007

Van Camp, C. M., Vollmer, T. R., & Daniel, D. (2001). A systematic evaluation of stimulus preference, response effort, and stimulus control in the treatment of automatically reinforced self-injury. *Behavior Therapy*, *32*, 603-613. doi: 10.1016/S000507894(01)80037-X

Vogel, J. R., Beer, B., & Clody, D. E. (1971). A simple and reliable conflict procedure for testing anti-anxiety agents. *Psychopharmacologia*, *21*, 1-7. doi: 10.1007/BF00403989

Worsdell, A. S., Iwata, B. A., Hanley, G. P., Thompson, R. H., & Kahng, S. (2000). Effects of continuous and intermittent reinforcement for problem behavior during functional communication training. *Journal of Applied Behavior Analysis*, *33*, 167-179. doi: 10.1901/jaba.2000.33-167

Table 1. *t* -test results for post condition anxiety ratings.

		Anxiety				
Condition	Level	*M*	SD	*t*	df	*p*
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			

Figure Captions

Figure 1. Approach-Avoidance (AA) model. The AA model highlights the competition for behavior between appetitive (e.g., playing soccer) and aversive (e.g., an approaching spider) stimuli and transitions that occur. Each component of the model highlights different responses programmed in our AA laboratory task (FR = fixed ratio schedule of reinforcement).

Figure 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, a1 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.

Figure 3. Verbal reports of anxiety level for Experiment 1. A within-subjects 2x2 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 subject 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 subjects. 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).

Figure 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 subject. 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.

Figure 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 subject AA transitions for each experimental condition. (M= group mean)

Figure 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 subject results for Approach:Observe:Approach (filled bars) and Approach:Observe:Avoid (grey bars) for each experimental condition. (M=group mean)

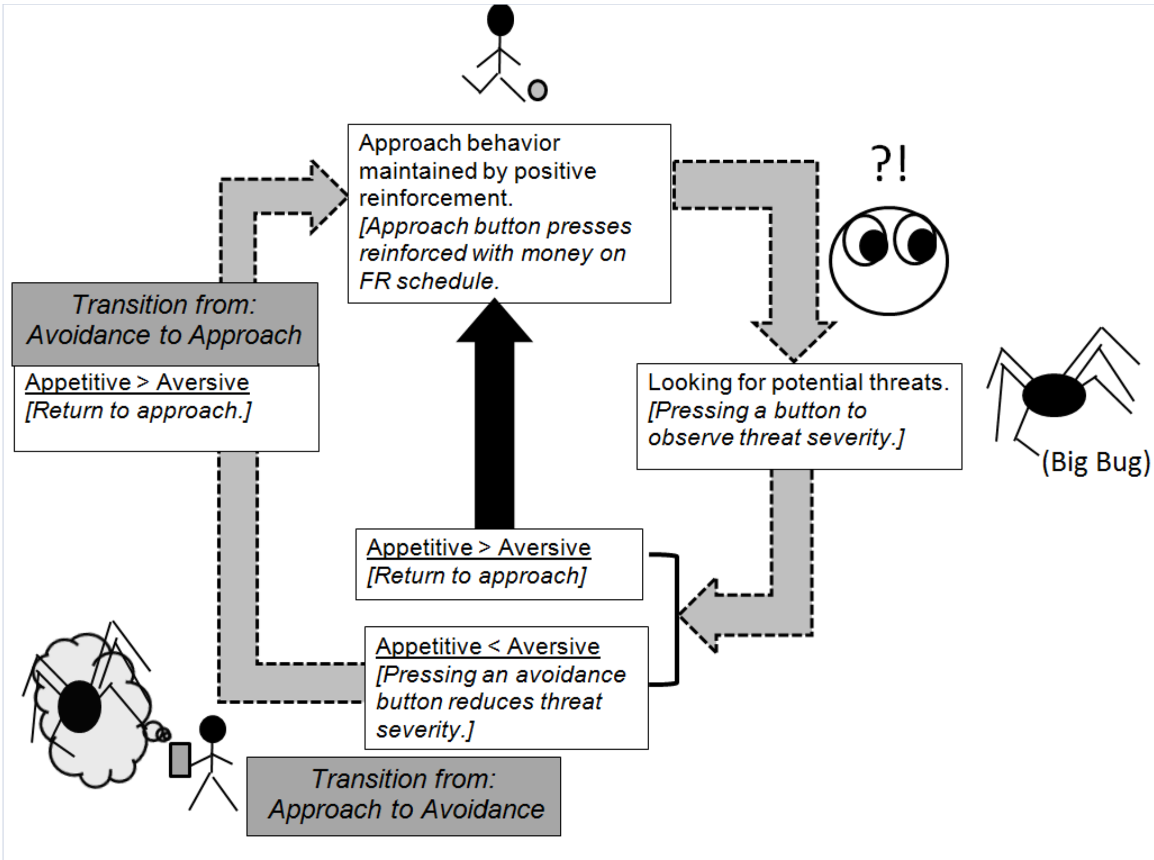
Figure 7. Earnings during Experiment 1. [A] Group mean earnings showed a significant decline with increased avoidance cost (FR 2 to FR20) but not increased threat magnitude ($0.01 to $0.40). (Bars represent 95% confidence intervals.) [B] Individual subject results showed a marginal decline in earnings 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)

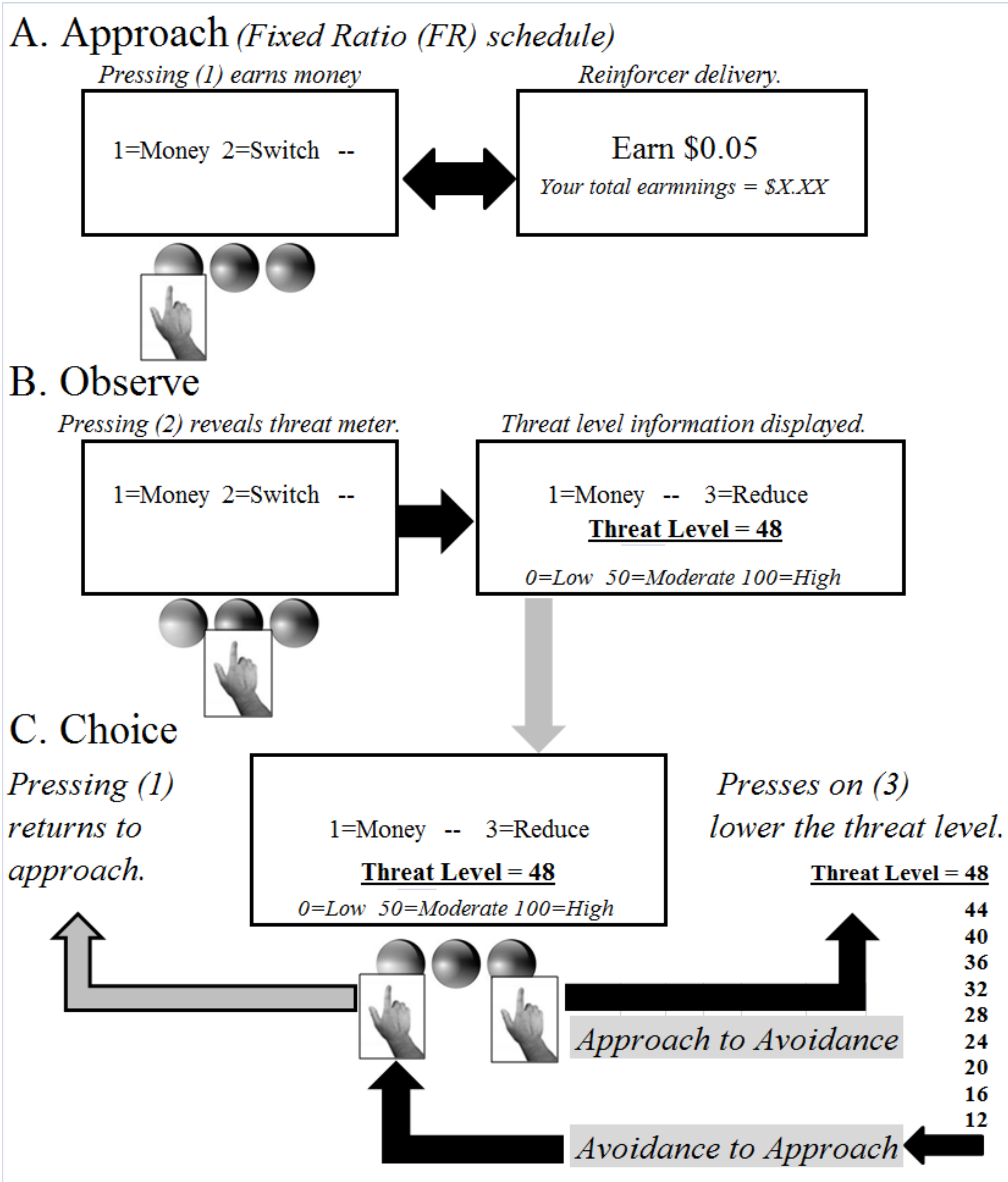
Figure 8. Cycles of human approach-avoidance behavior during Experiment 2. Each column presents data from Available, Unavailable and Inaccurate threat conditions for one representative subject. Top and middle rows show cumulative and total approach and avoidance responses for a 100 s period. Available 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.

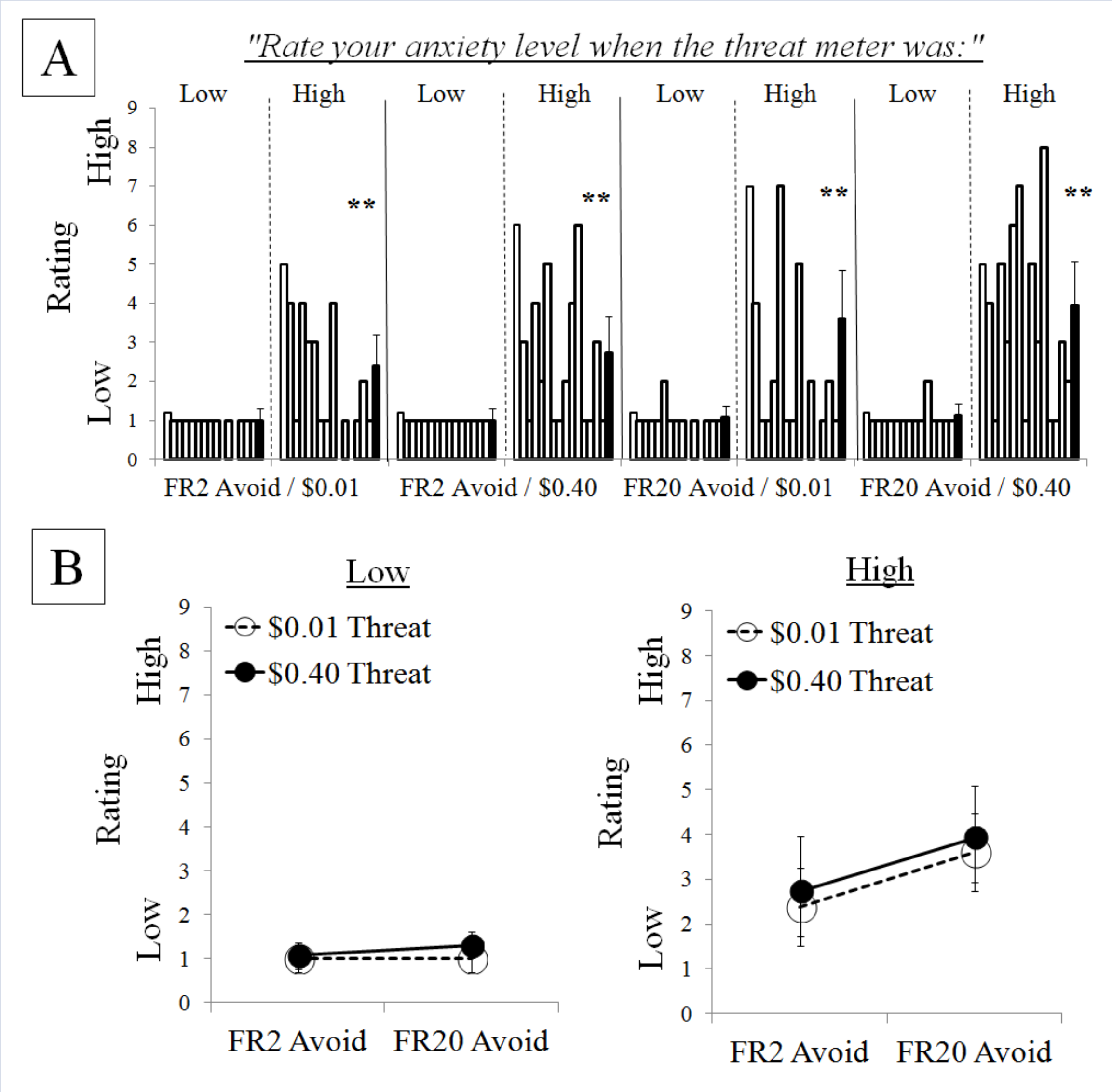
Figure 9. Group AA transitions and observing frequencies during Experiment 2. [A] Group mean threat levels associated with transitions from (left panel) 'Approach to Avoidance' and (right panel) 'Avoidance to Approach.' Inaccurate condition transitions for 'Approach to Avoidance' were significantly higher 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)

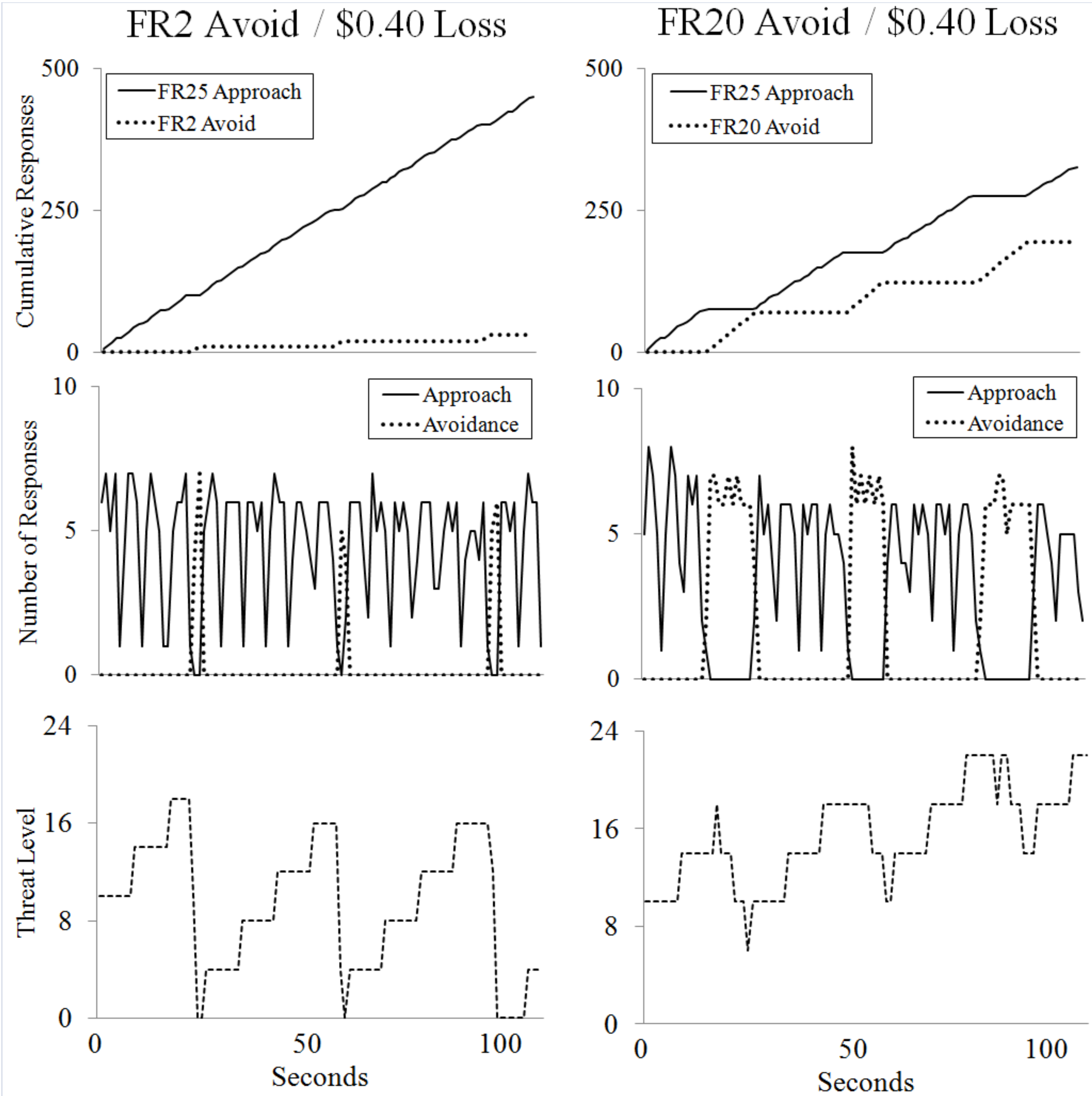
Figure 10. Individual subject AA transitions and observing frequencies during Experiment 2. [A] AA transition points that reflect threat levels associated with >50% probability of switching from 'Approach to Avoidance' (top of bar) and >50% probability of switching from 'Avoidance to Approach' (bottom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

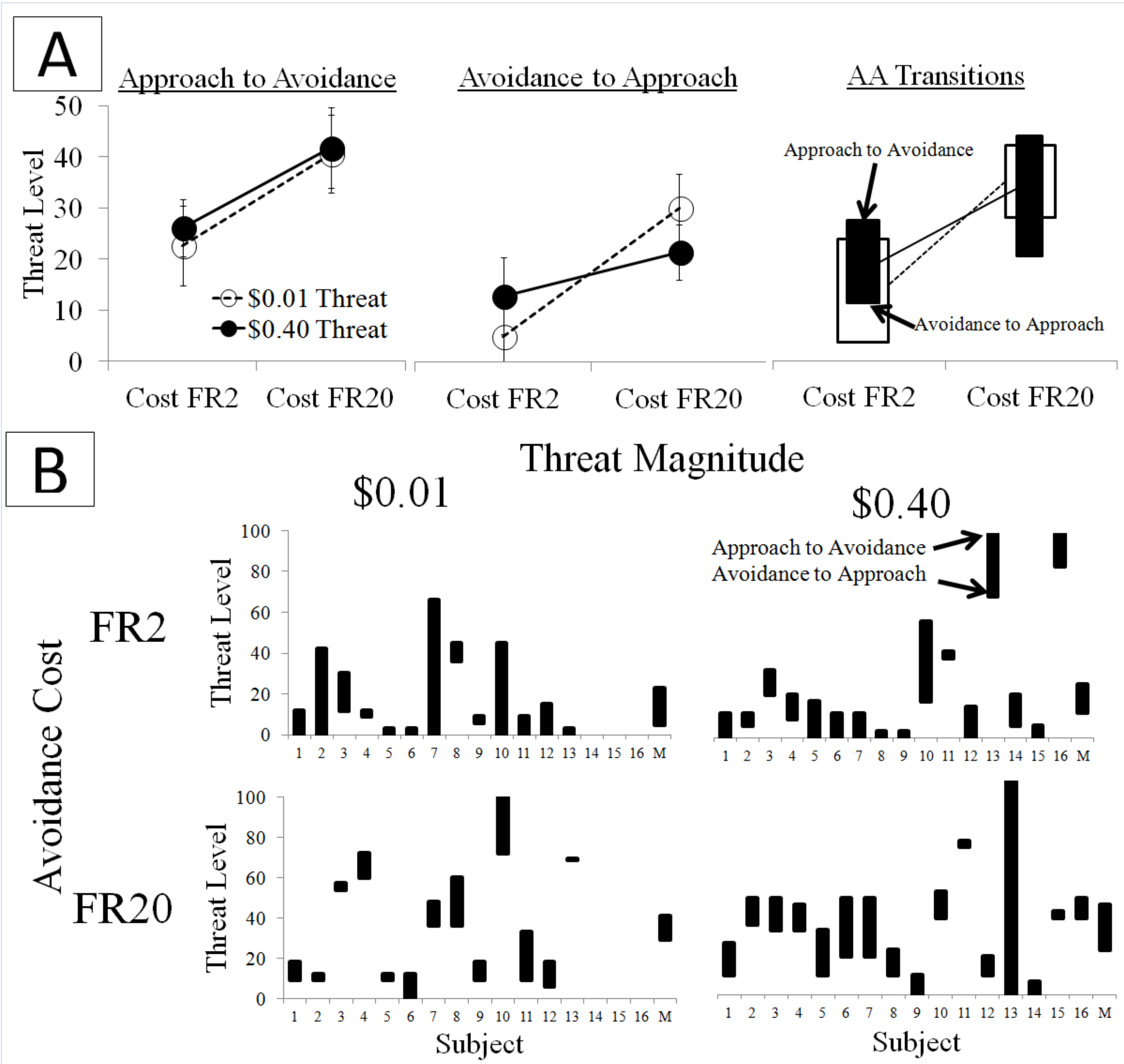
Figure 11. Earnings and frequency of loss contacts during Experiment 2. [A] Individual subject (open circles) and group mean (filled rectangles) earnings plotted for Available, Unavailable and Inaccurate threat conditions for three blocks. For block 3, earnings were significantly greater when threat 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.

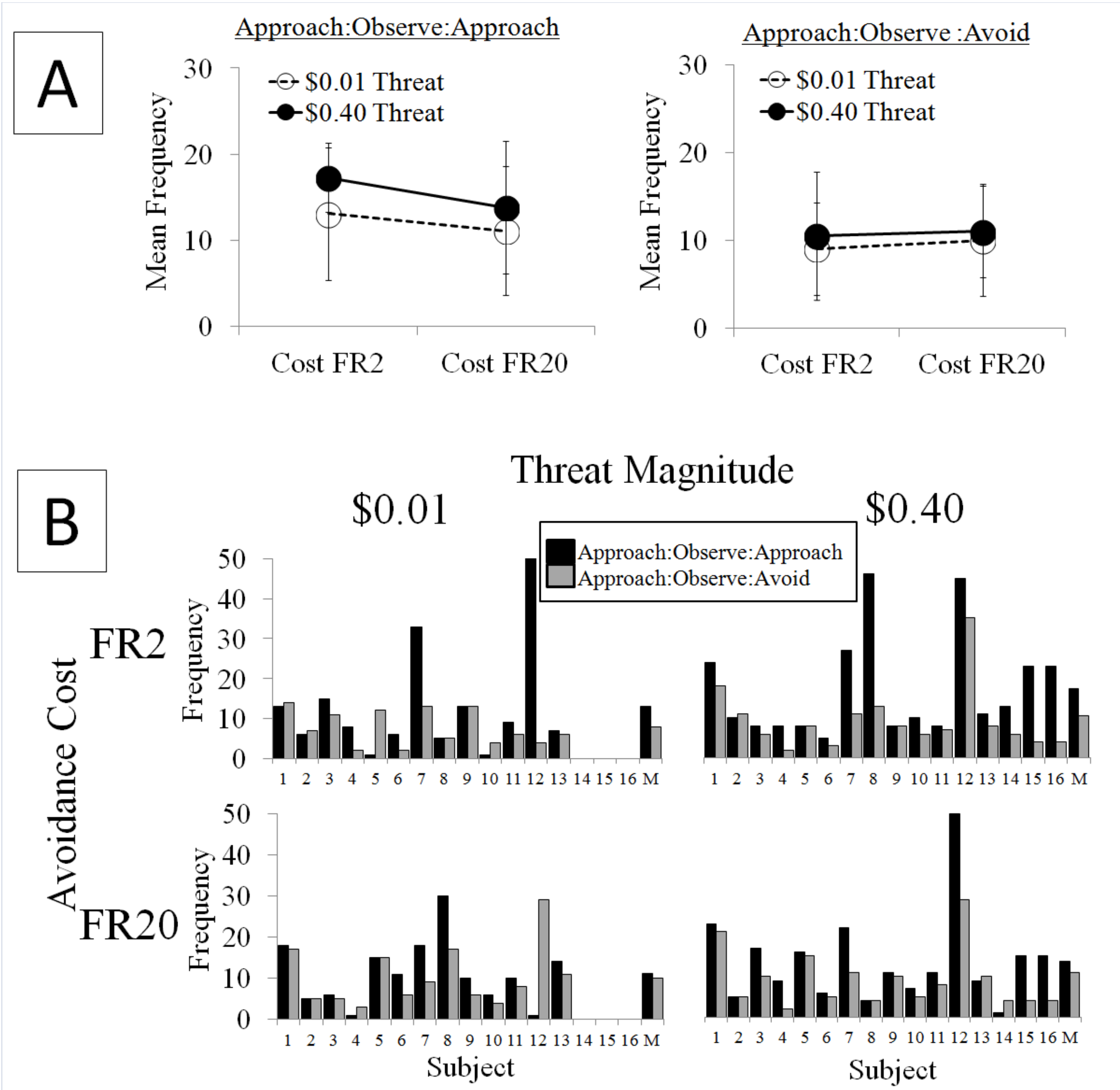

Approach behavior maintained by positive reinforcement.
[Approach button presses reinforced with money on FR schedule.
?!
Transition from: Avoidance to Approach
Appetitive > Aversive
[Return to approach.]
Looking for potential threats.
[Pressing a button to observe threat severity.]
(Big Bug)
Appetitive > Aversive
[Return to approach]
Appetitive < Aversive
[Pressing an avoidance button reduces threat severity.]
Transition from: Approach to Avoidance

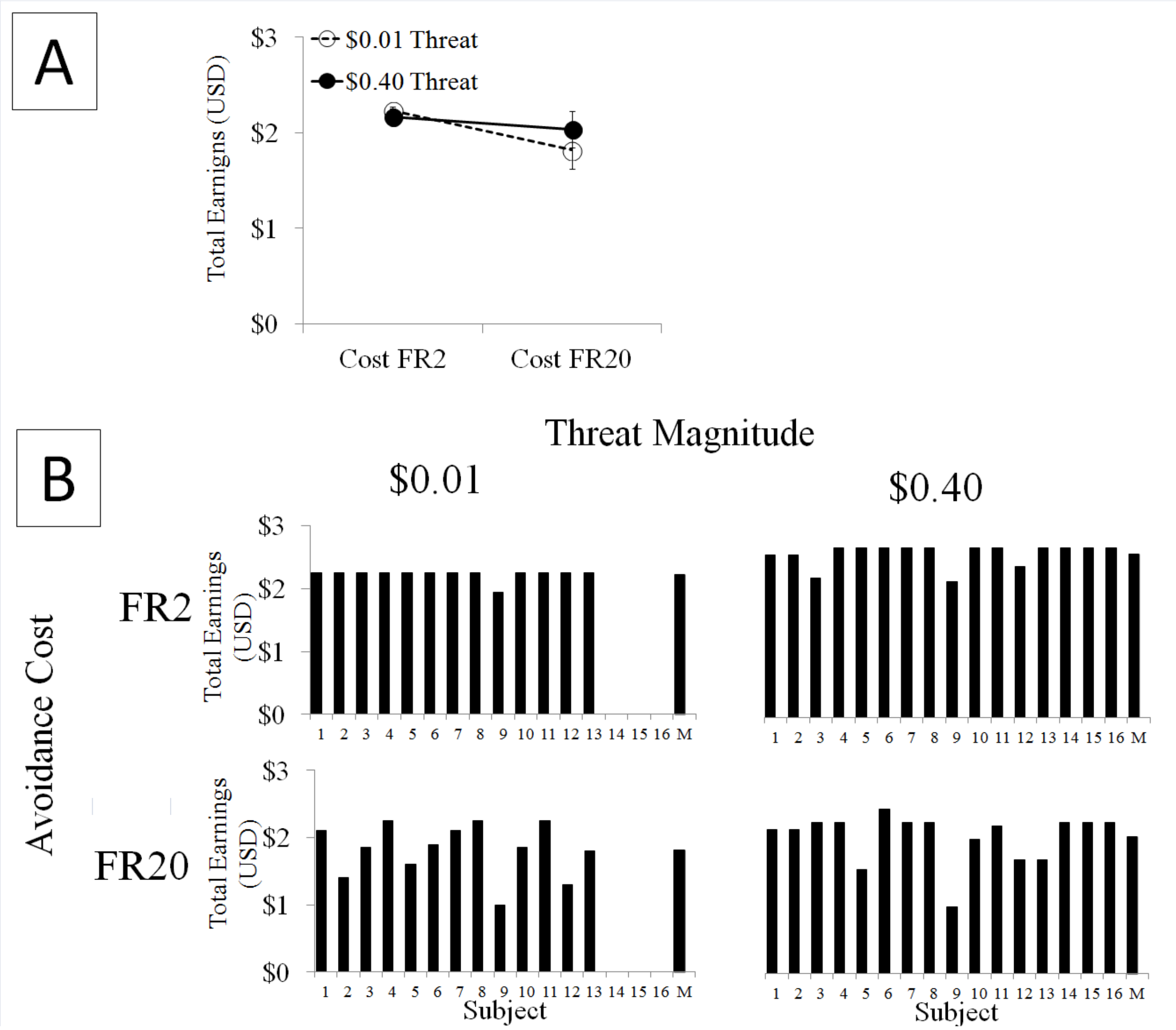

A. Approach (Fixed Ratio (FR) schedule)
Pressing (1) earns money
Reinforcer delivery.
1=Money 2=Switch --
Earn $0.05
Your total earmnings = $X.XX
B. Observe
Pressing (2) reveals threat meter.
Threat level information displayed.
1=Money 2=Switch --
1=Money -- 3=Reduce
Threat Level = 48
0=Low 50=Moderate 100=High
C. Choice
Pressing (1) returns to approach.
1=Money -- 3=Reduce
Threat Level = 48
0=Low 50=Moderate 100=High
Presses on (3) lower the threat level.
Threat Level = 48
44
40
36
32
28
24
20
16
12
Approach to Avoidance
Avoidance to Approach

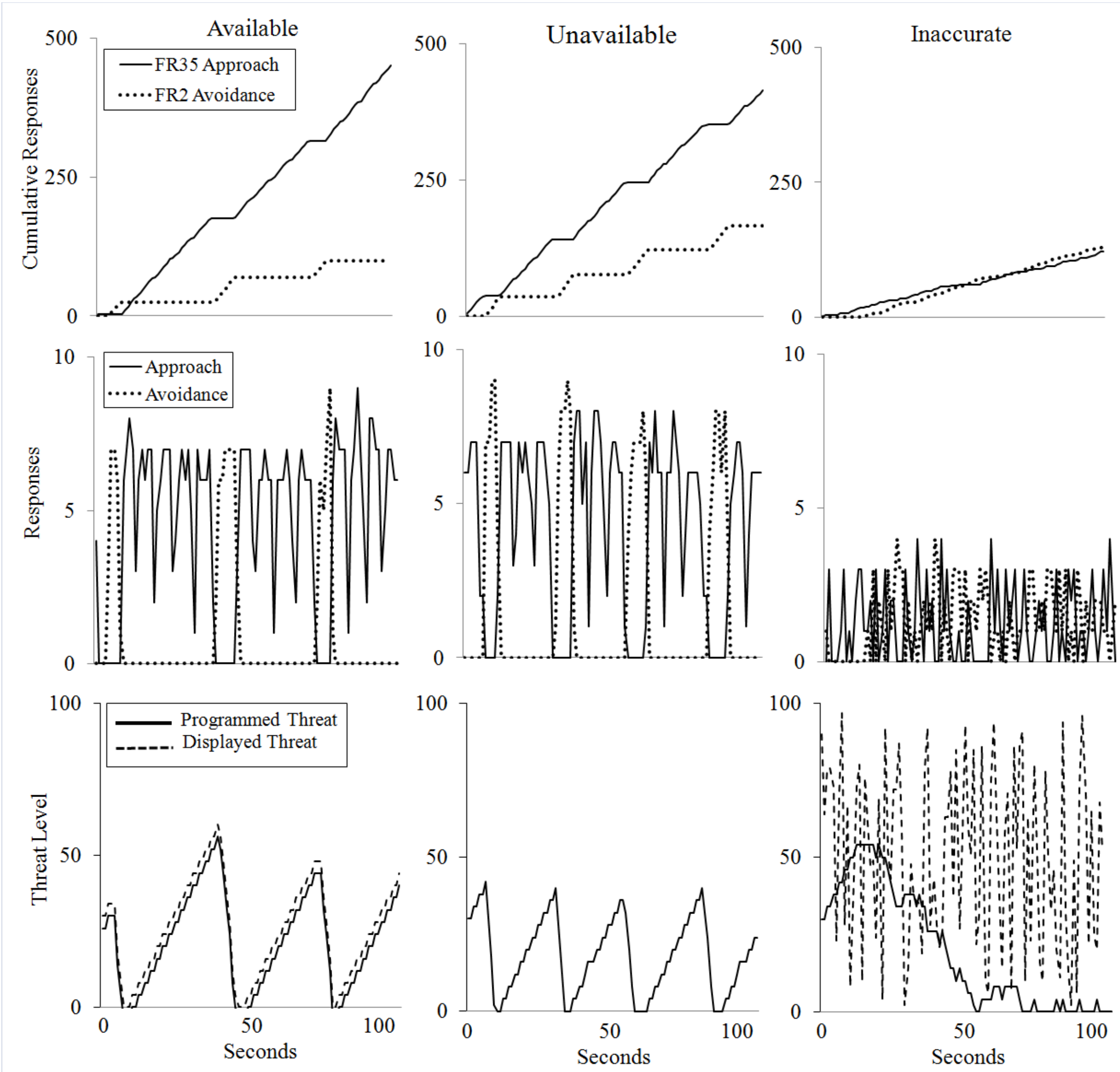

A
"Rate your anxiety level when the threat meter was:"
Low
High
Rating
**
FR2 Avoid / $0.01
FR2 Avoid / $0.40
FR20 Avoid / $0.01
FR20 Avoid / $0.40
B
Low
High
$0.01 Threat
$0.40 Threat
Rating
FR2 Avoid
FR20 Avoid

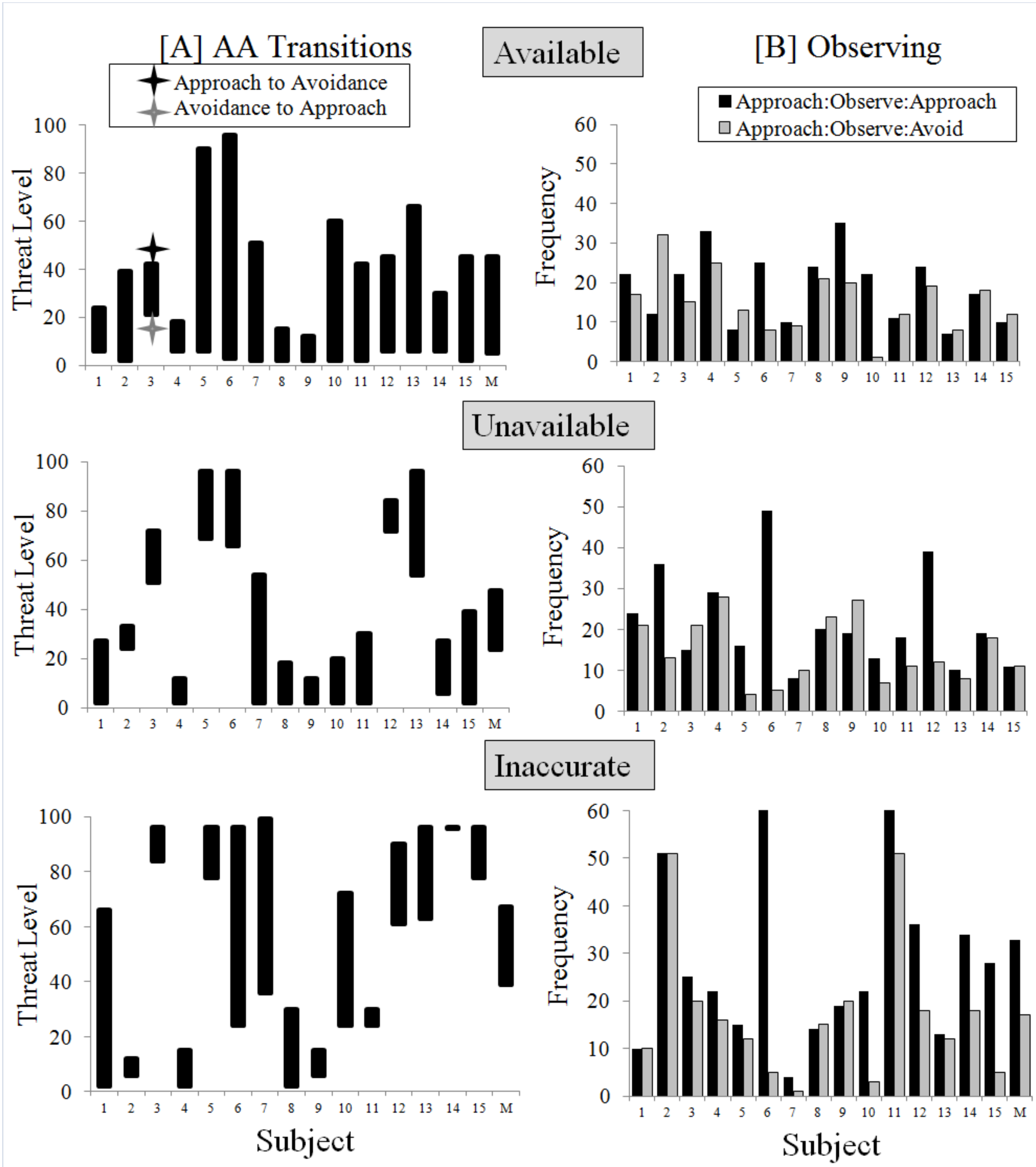

FR2 Avoid / $0.40 Loss
FR20 Avoid / $0.40 Loss
FR25 Approach
FR2 Avoid
FR20 Avoid
Approach
Avoidance
Cumulative Responses
Number of Responses
Threat Level
Seconds
500
250
0
10
5
24
16
8
50
100

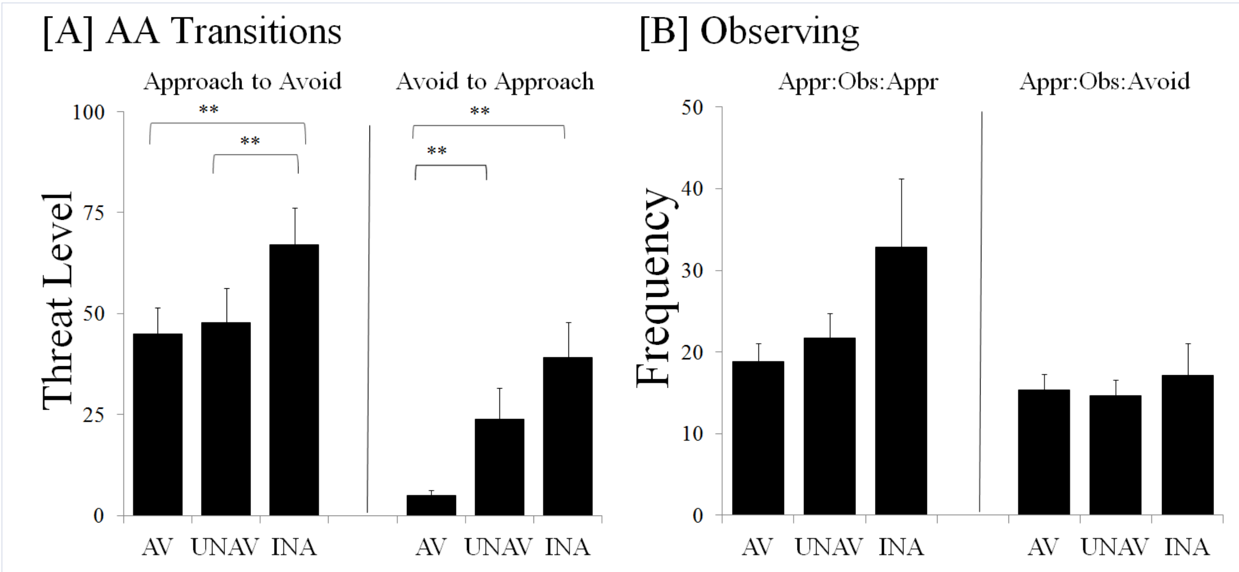

A
Approach to Avoidance
Avoidance to Approach
AA Transitions
Threat Level
$0.01 Threat
$0.40 Threat
Approach to Avoidance
Avoidance to Approach
Cost FR2
Cost FR20
B
Threat Magnitude
$0.01
$0.40
Avoidance Cost
FR2
FR20
Threat Level
Approach to Avoidance
Avoidance to Approach
Subject

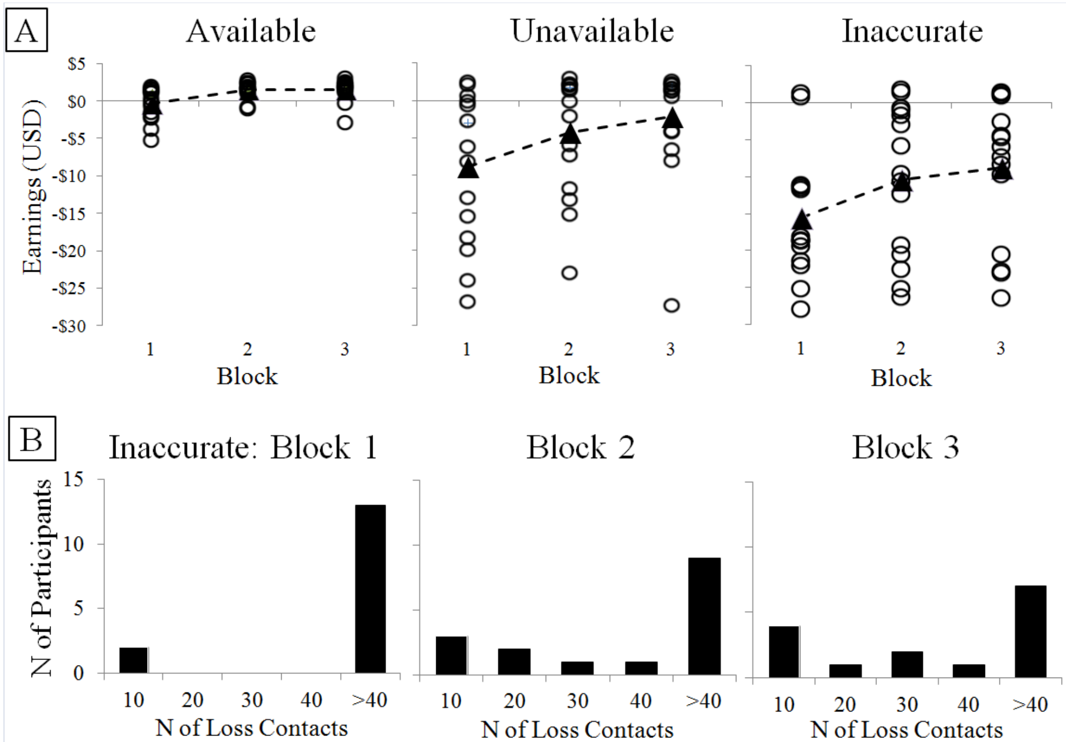

A
Approach:Observe:Approach
$0.01 Threat
$0.40 Threat
Mean Frequency
Cost FR2
Cost FR20
Approach:Observe :Avoid
B
Threat Magnitude
$0.01
$0.40
Approach:Observe:Approach
Approach:Observe:Avoid
Avoidance Cost
FR2
FR20
Frequency
Subject


A
$3
$2
$1
$0
Total Earnigns (USD)
$0.01 Threat
$0.40 Threat
Cost FR2
Cost FR20
B
Threat Magnitude
$0.01
$0.40
Avoidance Cost
FR2
FR20
Total Earnings (USD)
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 M
Subject


Available
Unavailable
Inaccurate
Cumulative Responses
FR35 Approach
FR2 Avoidance
500
250
0
Responses
Approach
Avoidance
10
5
0
Threat Level
Programmed Threat
Displayed Threat
100
50
0
50
100
Seconds


[A] AA Transitions
Approach to Avoidance
Avoidance to Approach
Available
[B] Observing
Approach:Observe:Approach
Approach:Observe:Avoid
Threat Level
Frequency
Unavailable
Inaccurate
Subject
Subject


[A] AA Transitions
Approach to Avoid
Avoid to Approach
Threat Level
100
75
50
25
0
**
**
**
**
AV
UNAV
INA
AV
UNAV
INA
[B] Observing
Appr:Obs:Appr
Appr:Obs:Avoid
Frequency
50
40
30
20
10
0
AV
UNAV
INA
AV
UNAV
INA


A
Available
Unavailable
Inaccurate
Earnings (USD)
$5
$0
-$5
-$10
-$15
-$20
-$25
-$30
1
2
3
Block
B
Inaccurate: Block 1
Block 2
Block 3
N of Participants
15
10
5
0
10
20
30
40
>40
N of Loss Contacts