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Not all risk taking behavior is bad: Associative sensitivity predicts learning during risk taking among high sensation seekers

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ABSTRACT

Risk taking behavior can be both adaptive and maladaptive depending on context. The majority of studies on risk taking, however, focus on clinical populations and dangerous or harmful risk taking. Individual differences in learning during risk taking are rarely examined in relation to task performance. The present study examined risk taking and associated outcomes in an exploration-based instrumental learning task (Balloon Emotional Learning Task; BELT), which presented a series of balloons in which participants pump up for points. Consistent with prior work, sensation seeking predicted increased risk taking behavior. Importantly, however, a significant interaction between sensation seeking and associative sensitivity, an attentional construct defined as the frequency and remoteness of automatic cognitive activity, was found. Specifically, among individuals high in sensation seeking, associative sensitivity predicted fewer balloon explosions and an increase in points earned on the balloon condition with the most potential for feedback driven learning. Thus, these findings suggest that sensation seekers are a heterogeneous group, and secondary traits such as associative sensitivity moderate risk taking and learning according to context.

1. Introduction

Given their clinical and public health consequences, studies of risk taking have largely focused on potentially harmful risk taking behaviors, their negative consequences, as well as identifying individuals likely to engage in these behaviors. However, as Boyer (2006) noted, "Risk-taking behaviors are not entirely foolhardy… and may be the most rational course of action given one's priorities" (p. 336). For example, while foraging behavior may increase risks of predation (Godin & Smith, 1988), hungry animals are more likely to engage in such behavior in order to reduce the risk of starvation (Van der Veen & Sivars, 2000). Thus, as a group, risk takers may be heterogeneous. Discriminant function analysis of three different groups of risk takers found that rock climbers were high on sensation seeking, residents in a long-term drug treatment facility were high on antisocial function, while police and firemen decorated for safety were lower on both sensation seeking and antisocial function, as their risk taking served a prosocial function (Levenson, 1990). These results suggest that individual differences in risk taking behaviors may be, in part, related to the functional utility of risk taking behavior, and as a result, temperament correlates may not be easily identified via a "one size fits all" approach.

1.1. Individual differences in risk taking

Although self-report measures of individual differences in risk taking, such as those that assess temperament and personality, correlate with real world risk behavior (e.g., Schwebel, Severson, Ball, & Rizzo, 2006), the use of experimental behavioral tasks may be better able to assess real-world risk taking behavior and interrogate the neurobiology of risk behavior (Jentsch, Woods, Groman, & Seu, 2010). The Balloon Analogue Risk Task (BART; Lejuez et al., 2002) has been used widely as a laboratory analogue of individual differences in risk taking. Behavior on the BART is predicted by sensation seeking (SS) (Lejuez et al., 2002), though this task has largely been used to assess risk taking in clinical populations (e.g., Hopko et al., 2006; Lejeuz, Aklin, Jones, Richards, & Read, 2003).

Tasks that measure tendencies to explore and seek out opportunities need not be specific to clinical populations. Even in infancy, exploration of the environment is essential for learning and development (Piaget, 1954). BART-like tasks provide the opportunity to examine change across trials as a function of experience, allowing for the measurement of both individual differences in risk taking, and the relationship between risk taking and outcome on the task. For the BART, the stated goal is to achieve the highest payout at the end of the task. Learning can play a crucial role in success during this type of task. Participants receive immediate feedback (an additional point or a balloon explosion)

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following each press, which can guide future decision making under these conditions of risk. Gibson (1988) stated that exploring the world and learning about the world are "inextricably linked". Yet, heterogeneity in risk takers could be caused by how much they learn from their risk taking experience. The differences in the acquisition and use of relevant information may play an important role in moderating subsequent risk taking behavior. By examining how risk taking is altered in response to learning may provide a clearer picture of optimal versus suboptimal risk taking.

1.2. Learning and risk taking

Pickering and Gray (2001) stated that "the ability to detect and attend to salient stimuli may be particularly relevant in [stimulus–response] learning tasks in which the subject has to learn which stimulus features are predictive of the responses required..." (p. 115). The ability to make meaning from the associations in one's environment has clear evolutionary advantages, and like many cognitive processes, is expected to vary across the population. Associative sensitivity (AS), an attentional construct defined as "frequency and remoteness of automatic cognitive activity" (Evans & Rothbart, 2007), has not been examined in relation to learning. The similar Big Five construct of Openness to Experience (see Evans & Rothbart, 2007), has been described as attentiveness to inner feelings, sensitivity, and intellectual curiosity (Costa & McCrae, 1992). In fact, AS has been theorized to be the attentional disposition that "links" Openness to actual extraction of actionable information (see Van Egeren, 2009). Implicit learning (the automatic detection of associations in the environment) has shown moderate positive associations with Openness (Kaufman et al., 2010), though we propose that AS is likely to better predict such learning. Thus, we anticipate that both individual difference traits (i.e., SS [sensitivity to rewards] and AS [sensitivity to stimulus–response associations in the environment]) would be relevant in unique ways to risk taking behavior over time.

1.3. Aims and hypotheses

The current study modified the BART to provide a tool to examine changes in risk taking behavior depending on implicit contextual information. The modified task, Balloon Emotional Learning Task (BELT), contained two stable (certain) and one variable (uncertain) balloon condition. The inclusion of balloon conditions with fixed explosion points allowed for a more direct examination of learning such parameters via task experience, as the fixed information can better guide subsequent risk taking behavior, as opposed to 'ill-defined' tasks such as the BART (see Pleskac, 2008). Conditions were denoted by balloon color with initially unknown meaning to participants in order to facilitate measurement of individual differences in tracking the balloon condition and differentiation of behavior from the beginning to the end of the task. The current task is well-suited for assessing risk taking and learning for the following reasons: (1) rather than measuring a single behavioral response to a single stimulus (e.g., Corr, Pickering, & Gray, 1995), participants determine the number of presses to make (that is, to "push the limit" of each balloon trial), thus providing a laboratory measure of risk taking and (2) the inclusion of three balloon conditions provides the ability to capture separable risk taking and learning outcomes.

We hypothesized that SS would predict risk taking (i.e., pumps, balloon explosions) as found in previous research on the BART (Lejuez et al., 2002). However, we also anticipated that sensations seekers would be a heterogeneous group. Therefore, based on Pickering and Gray's (2001) predictions regarding individual differences in associative learning, we hypothesized that AS would moderate the association between SS and task outcome.

2. Method

2.1. Participants

Seventy-six (26 male, 50 female) undergraduates from a large public university in the Western United States who received partial class requirements for participation. Participants were required to be at least 18 years of age or older and English speaking. This sample ranged in age from 18–26 years old ($M = 20.15$, $SD = 1.70$). One participant was excluded as an outlier due to scores falling beyond three standard deviations from the mean.

2.2. Tasks and measures

2.2.1. Balloon Emotional Learning Task (BELT)

All participants completed a computerized associative learning task in which participants would press a button to "pump up" balloons and earn points for each balloon (i.e., more pumps earned more points). Too many pumps would result in balloon explosions, which occurred at an initially unknown number of pumps, resulting in the loss of all points for that trial. Balloons appeared in three colors with different response contingencies, counterbalanced across participants. Pink balloons exploded at 19 pumps (certain-long), orange balloons exploded at 7 pumps (certain-short), and blue balloons exploded variably at 7 pumps, 13 pumps, or 19 pumps distributed equally across each third of the task (uncertain). There were 27 trials, and balloon color was distributed evenly across the task. Participants were not told that colors signified different response contingencies, but were explicitly told that not all balloons pop at the same point. Thus, the task involved associative instrumental learning because participants could make cause-effect determinations by altering their own behavior through learning how balloon color relates to task structure. In this way, the task is 'defined' given that the underlying task structure can be determined, unlike other risk taking tasks (e.g., BART).

2.2.2. Adult Temperament Questionnaire – short form (ATQ; Rothbart, Ahadi, & Evans, 2000)

This 77 item self-report measure of temperament obtains five general factors of temperament. Likert-scale ratings ranging from 1 (extremely untrue) to 7 (extremely true) were obtained on each item, and scales were composed of the mean of all items. For the present study we used the AS scale (example item: "I sometimes seem to understand things intuitively"). Previous work has found that the ATQ is correlated with individual difference traits measured using other well-validated instruments (e.g., Derryberry, Reed, & Pilkenton-Taylor, 2003), and the AS scale has been shown to have good internal consistency (.85) (Evans & Rothbart, 2007).

2.2.3. UPPS-P impulsivity scale (Lynam, Smith, Whiteside, & Cyders, 2006)

This 59 item self-report measure assesses several domains of impulsivity. Likert-scale ratings ranging from 1 (agree strongly) to 4 (disagree strongly) were obtained on each item, and scales were composed as the sum of the items. In the present study, we used the SS scale, which has been shown to have excellent internal consistency (.90) and demonstrated discriminate validity from other factors of impulsivity (Whiteside & Lynam, 2003).

2.3. Data Analysis

We prioritized three outcome variables: (1) *pumps* as a measure of general risk taking, (2) *points* as a measure of outcome, and (3) *explosions* as a measure of untempered risk taking. We examined these by the type of balloon presented (certain-long, uncertain, certain-short), as well as by task third (i.e., first, second, and third) given that balloon conditions were presented equally across task third. Pairwise comparisons were conducted using Fisher's least significant difference (LSD) post hoc test to probe rule acquisition group differences, thereby providing a conservative test to protect against Type I error. For analyses using SS or AS, participant's sex was included as a covariate. Sex was uncorrelated with all BELT outcomes ($p > .05$).

3. Results

3.1. Overall task behavior and outcome

See Table 1 for descriptive statistics of study variables. We conducted three separate 3 (balloon condition [certain-short, certain-long, and uncertain]) × 3 (task third) repeated measures ANOVAs for the dependent measures of pumps, points, and explosions. For pumps, as expected based on the task design, a main effect was found for balloon condition, $F(2,148) = 67.42$, $p < .001$, partial $\eta^2 = .48$, with the greatest number of pumps on the certain-long balloons, followed by uncertain balloons, and then certain-short balloons. While no main effect was found for task third, a significant balloon condition by task third interaction was found, $F(4,296) = 6.78$, $p < .001$, partial $\eta^2 = .08$. The interaction was driven by a strong decline in pumps made across the uncertain trials, compared to a more stable risk taking on the other balloon conditions.

For our measure of BELT outcome, points earned, a main effect was found for balloon condition, $F(2,148) = 210.63$, $p < .001$, partial $\eta^2 = .74$, such that the most points were earned in the certain-long condition, followed by the uncertain condition, and then the certain-short condition. A main effect was also found for task third, $F(2,148) = 24.53$, $p < .001$, partial $\eta^2 = .25$, such that points increased linearly across the task, indicating an improvement in performance with greater task experience. No balloon condition by task third interaction was found.

For our measure of untempered risk taking, explosions, a main effect was found for balloon condition, $F(2,148) = 200.45$, $p < .001$, partial $\eta^2 = .73$, such that most explosions occurred in the certain-short balloons, followed by uncertain balloons, and then certain-long balloons. A main effect was also found for task third, $F(2,592) = 28.83$, $p < .001$, partial $\eta^2 = .28$, such that there was a linear reduction in explosions across the task. A significant balloon condition by task third interaction was also found, $F(4,296) = 4.21$, $p = .002$, partial $\eta^2 = .05$. Explosions sharply declined for the certain-short condition and uncertain condition, but not for the certain-long condition. Taken together, the pumps, points, and explosion data suggest that participants were able to learn the task parameters across the testing session.

Table 1
Mean (SD) for pumps, points, and explosions by task third and balloon condition.

	First third	Second third	Last third
Pumps			
Certain-short	18.53 (1.98)	18.48 (1.69)	18.20 (1.85)
Uncertain	25.13 (7.74)	22.44 (5.46)	21.93 (5.22)
Certain-long	29.41 (12.12)	29.28 (11.63)	30.91 (13.10)
Points			
Certain-short	6.49 (4.43)	8.03 (5.21)	10.64 (5.08)
Uncertain	14.15 (5.38)	15.39 (4.01)	16.23 (4.17)
Certain-long	24.85 (9.08)	27.00 (8.94)	28.37 (10.28)
Explosions			
Certain-short	1.72 (0.85)	1.49 (0.92)	1.08 (0.93)
Uncertain	1.15 (0.78)	0.89 (0.58)	0.75 (0.59)
Certain-long	0.24 (0.54)	0.12 (0.33)	0.13 (0.34)

3.2. Sensation seeking and risk taking

Previous work on individual differences in risk taking has emphasized the role of SS and risk taking behavior. We conducted separate 3 (condition) × 3 (third) repeated measures ANOVAs for pumps made with centered SS included in the model as a covariate. As predicted based on prior work (e.g., Lejuez et al., 2002), there was a between-subjects effect of SS on risk taking across the task, $F(1,71) = 5.73$, $p = .02$, partial $\eta^2 = .08$ (Fig. 1). Findings were highly consistent using Average Adjusted Pumps as the outcome measure (Lejuez et al., 2002), though several participants were lost due to missing data (i.e., all balloons were exploded in a given condition in one third and no score could be calculated), $F(1,47) = 7.72$, $p = .01$, partial $\eta^2 = .14$. In both cases, participants with higher levels of SS made more pumps throughout the task. In addition, SS significantly interacted with balloon condition, $F(2,142) = 4.04$, $p = .02$, partial $\eta^2 = .05$, such that there was an association between SS and pumps for the two stable balloon conditions (short and long) but not for the variable condition. SS did not significantly interact with task third and the three-way interaction of SS by balloon condition and task third was not significant. These findings indicate that SS did not predict a change in risk taking behavior across the task. In addition, confirming previous work, the same general pattern was found for explosions. Again, there was a between-subjects effect of SS on explosions across the task, $F(1,71) = 4.39$, $p = .04$, partial $\eta^2 = .06$, such that participants with higher levels of SS made more explosions. No two-way or three-way interactions with SS and balloon condition or task third emerged.

3.3. Associative sensitivity and learning

Taken together, these findings replicate previous work on the BART, such that SS predicted increased risk taking (i.e., number of pumps made and balloon explosions). However, because the BELT allowed for an assessment of learning (particularly in the certain-short condition, as feedback [i.e., explosions] was most likely to be encountered, see Table 1), we chose the certain-short balloon condition to examine the potential moderating effect of AS on the functional outcome of risk taking behavior (i.e., balloon explosions and points earned). Following the approach of previous studies (e.g., Palmgreen, Donohew, Lorch, Hoyle, & Stephenson, 2001; Rosenbloom, 2003), we dichotomized our sample into a low and high sensation seekers based on their mean score. AS was also dichotomized into high and low groups and both SS and AS were entered into a repeated-measures ANOVA (first third vs. last third) as between-group variables. A significant SS × AS interaction predicted explosions in the certain-short condition, $F(1,68) = 4.40$, $p = .04$, partial $\eta^2 = .06$. Specifically, the high SS/high AS group made fewer explosions on the last third of the task compared to both the high SS/low AS and low SS/high AS groups (Fig. 2A). We repeated this analysis using points earned across the task, and again found a significant SS by AS interaction, $F(1,68) = 4.29$, $p = .04$, partial $\eta^2 = .06$ (Fig. 2B). Posthoc probing revealed that among individuals high in SS, those who were also high on AS had greater gains in points earned than those with low AS. Analyses were conducted using continuous variables with results in the same direction. As such, it was postulated that among a group expected to be high risk takers, the outcome of the risk

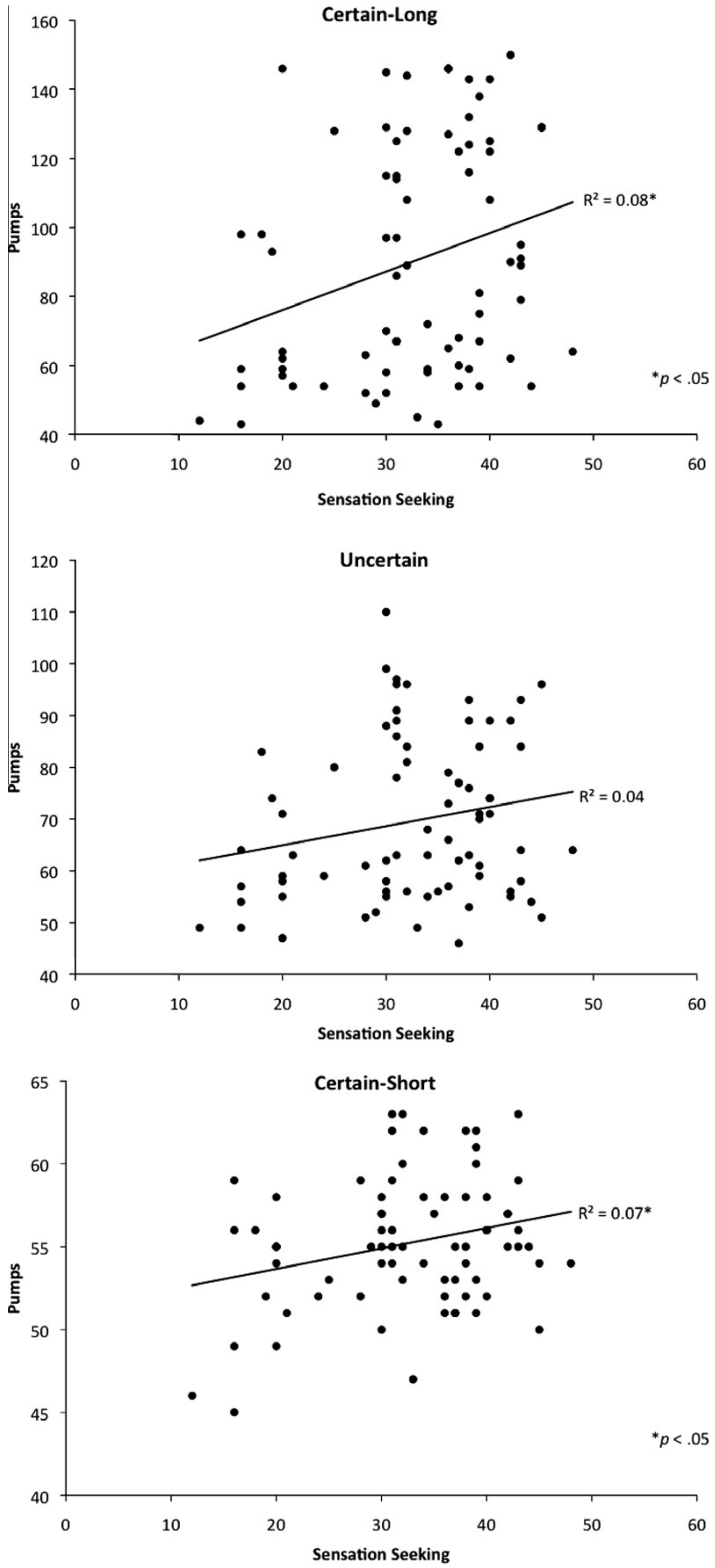

Fig. 1. Sensation seeking predicted increased risk taking across the task for certain-long, uncertain, and certain-short balloon conditions.

taking behavior (i.e., points earned) may vary based on this secondary trait.

We next examined whether the avoidance of the explosions was responsible for the increase in points (subtracting first third

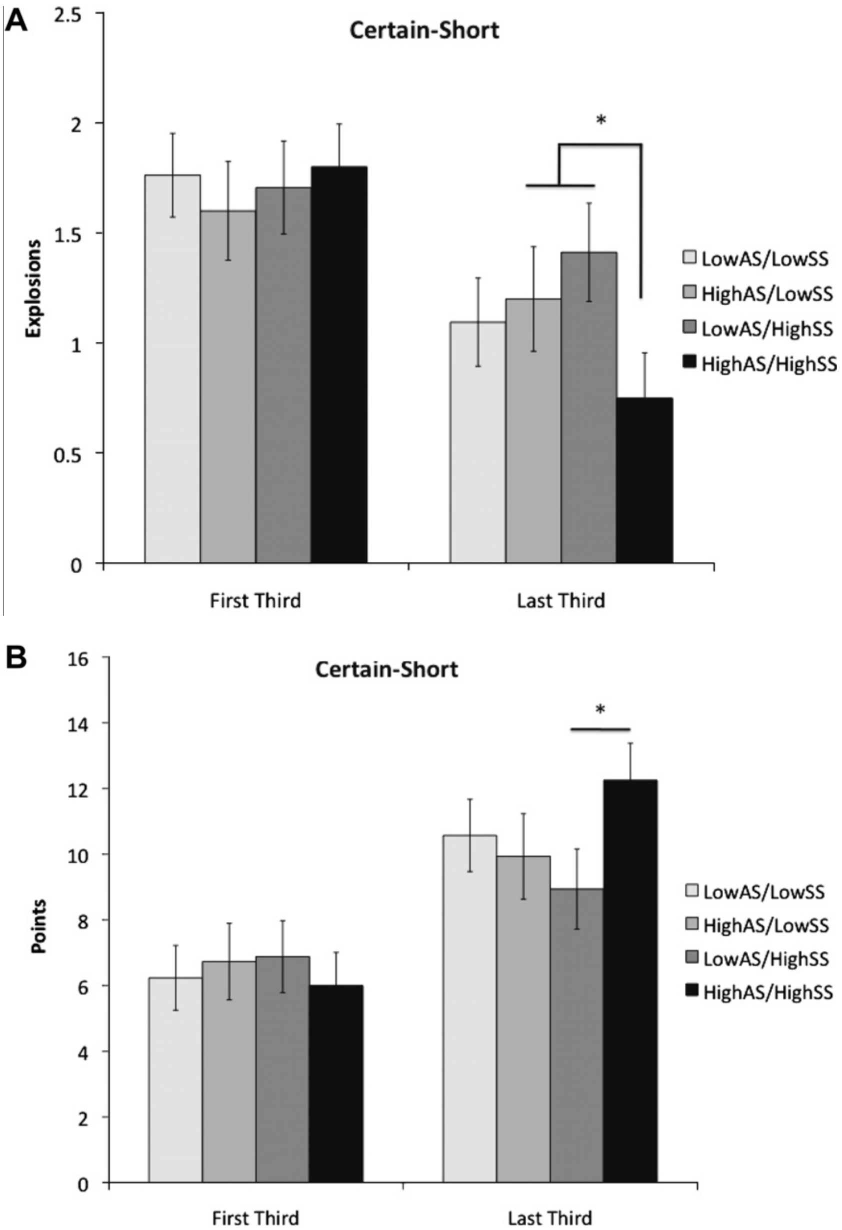

Fig. 2. A significant sensation seeking (SS) by associative sensitivity (AS) interaction was found for number of (A) explosions and (B) points on the last third of the task in the certain-short condition. Individuals high on both traits made fewer explosions and earned more points than those high in SS but low in AS.

from last third) during the short balloon condition. Accordingly, we tested whether the association between AS and the increase in points was mediated by a change in explosions (subtracting first third from last third) separately for the low SS and high SS groups. As can be seen in Fig. 3A, in the low SS group, AS was unrelated to outcome. In contrast, for the high SS group, AS scores predicted the outcome. As shown in Fig. 3B, we conducted a mediation analysis using a nonparametric resampling method to derive the 95%CI for the indirect effect of the AS through a change in explosions on the change in points earned, using the SPSS Macro provided by Preacher and Hayes (2008). For AS predicting the change in points, the true indirect effect was estimated to lie between 0.38 and 7.41 (95%CI). Because zero is not within the 95%CI, the indirect effect is significantly different from zero at $p < .05$. These analyses suggest that AS moderates the association of high risk taking and points through the avoidance of poor risk taking (i.e., pressing balloons to the explosion point), thus resulting in an increase in points.

4. Discussion

Consistent with previous work, SS predicted increased risk taking on a computerized risk taking laboratory task (Lejuez et al., 2002). While there was a main effect of SS on risk taking during the task, the combination of SS plus AS was associated with better performance, as AS predicted more avoidance of balloon explosions (while maintaining sufficient pumps to obtain increased points) for those individuals with high SS on the certain-short condition. Accordingly, AS emerged as useful for detecting patterns in the environment. Thus, whereas SS predicted general risk taking during the task, individuals high in SS and AS obtained the greatest number of points by the end of the task, but those high SS individuals with low AS obtained the fewest. A mediation analysis showed that for those individuals scoring high on SS, the AS trait was associated with increased points earned by the end of the task because of decreased explosions with greater task experience. This mediation suggests that higher levels of AS increased the high SS individuals'

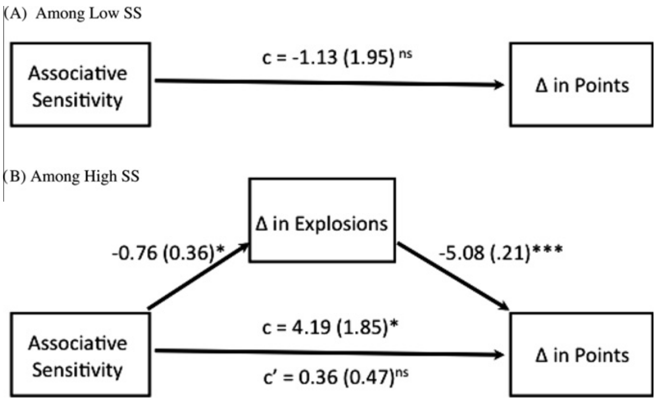

Fig. 3. (A) Among low sensation seekers associative sensitivity predicted no change in points earned for the certain-short condition. (B) Mediation Model: Among high sensation seekers the association between associative sensitivity and an increase in points is mediated via a reduction in balloon explosions on the certain-short condition. $^{*}p \leqslant .05$, $^{***}p<.001$.

learning to avoid explosions. These findings support the notion that sensation seekers are a heterogeneous group, and that heightened risk taking is not uniform among those high in SS. In particular, AS helped to guide appropriate behavior via forming associations provided by the environment in those high in SS.

The temperament trait of AS emerged as an important individual difference trait related to adaptive behavior on the task. AS moderated the association between SS and functional risk taking behavior, given that individuals high on both traits reduced risk taking when it was not adaptive (i.e., on the certain-short balloon condition). These findings are consistent with the adaptive function of some risk taking, and may provide insight into temperament differences in the ability to behave flexibly in response to a changing and variable environment. To date, this trait has been relatively neglected, as few studies have included AS in relation to risk taking. In a review of sensory processing sensitivity (Aron, Aron, & Jagiellowicz, 2012), it was stated that constructs such as AS motivate learning because heightened sensitivity "serve[s] the general evolutionary purpose of noticing more aspects of Situation A to make better choices in later Situation B" (p. 276). The results from the current study support this hypothesis and underscore the importance of considering AS in studies of learning and risk taking. Without examining a subject's sensitivity to associations, one may incorrectly predict that increased risk taking is associated with poor outcome. However, in a study of the BART in children, Humphreys and Lee (2011) found that risk taking increased with age, as older children pumped more on the task. Unpublished results from this study also indicated that increased risk taking was highly correlated with increased total points earned, suggesting that the increased risk taking observed may alternatively (or additionally) be viewed as adaptive behavior. Similarly, a recent study found that number of alcohol use disorder symptoms negatively correlated with adjusted mean pumps on the BART (Ashenhurst, Jentsch, & Ray, 2011). The majority of participants made a suboptimal number of pumps (i.e., participants generally fell on the left side of the U-shaped function between pumps and money earned), indicating that conservative BART behavior in those with greater symptoms also resulted in less money awarded at the end of the task.

Although SS may provide the drive to seek out new experiences and explore one's environment and opportunities, it does not guarantee success in those ventures. The positive association between SS and financial matters has been well documented (e.g., Grinblatt & Keloharju, 2009; Wong & Carducci, 1991). Yet, while there is a moderate effect size for traits such as SS or risk propensity in the prediction of entrepreneurship, recent reviews clarify that there are likely to be other personality traits that predict *successful* entrepreneurship (Rauch & Frese, 2007). Indeed, among entrepreneurs, social adaptability was found to significantly predict financial success (Baron & Markman, 2003). In a study of risk taking behaviors in college students, Fischer and Smith (2004) found that SS predicted both negative and non-negative risk taking behaviors, but that the separate construct of (lack of) deliberation predicted only the likelihood of engaging in maladaptive risk behaviors. Taken together, it appears that SS provides greater opportunities for potential successful (and failure) opportunities, but that it is important to consider secondary traits, including AS, in the role for tempering maladaptive risk taking through learning mechanisms. We encourage researchers to examine personality traits beyond SS as they pertain to risk taking and related performance.

The findings from the present study should be considered in light of important limitations. First, it is likely that, given a greater number of trials, learning might have eventually been observed among participants who did not show evidence of learning during the task. Another important limitation is that the present task includes both rewards (points) and punishment (removal of points) simultaneously, which precludes the ability to examine the potential differences motivated by these two factors. Future research should consider including approach related instrumental learning tasks that vary reward and punishment to allow for the independent examination of these motivating factors.

5. Conclusions

The present study supports the finding that temperament influences risk taking on a novel task. Importantly, we measured the heterogeneity in risk taking as it relates to specific contexts. In the current study, under conditions that allow for learning (i.e., the stable conditions), individuals learned and subsequently gained more points on trials across the task. We found evidence for individual differences in temperament that were associated with learning. SS was associated with increased risk taking on the task, but it was the combination of high SS and high AS that resulted in optimal performance (i.e., decreasing explosions and increasing points). Disentangling SS from learning may be useful in understanding the predictors of successful versus unsuccessful risk taking behavior.

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