RISK-TAKING IN PERCEPTUAL-MOTOR CONTROL: SEARCHING FOR INDIVIDUAL DIFFERENCES USING SPEEDED AIMING

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ABSTRACT

The aim of this study was to develop a simple laboratory task to determine the level of riskiness that individuals are willing to adopt in perceptual-motor tasks. Our participants chose between aiming for one target or another in each trial, where one target had a lower index of difficulty than another but also a lower potential score. We found that participants differed in their risk-taking in this situation. In addition, we found that participants whose risk-taking was extreme -- either exceptionally conservative or exceptionally liberal -- made suboptimal decisions about which target to aim for over and above their basic movement abilities. The method offered here may be used to identify people at risk of accidents. The present results also call into question the generality of the finding from other studies that aiming is consistently optimal.

INTRODUCTION

The aim of this study was to develop a simple laboratory task that can be used to determine the level of risk that individuals are willing to adopt in perceptual-motor tasks. Such tasks, when carried out in the real world, can lead to accidents if they are undertaken with undue risk. It is therefore important to be able to predict who will take undue risks so measures can be taken to protect those individuals from themselves and others.

To our knowledge, no such task is currently available. Other measures of risk-taking are available, but they either take the form of questionnaires about what individuals say they do (e.g., Dulla & Ballard, 2003) or, if the measures concern actual behavioral choices, they tend to focus on financial betting rather than perceptual-motor control (Bechara, Damasio, Tranel, & Damasio, 1997). Financial betting and perceptual-motor control are different performance domains, notwithstanding the possibility that, at root, they rely on similar computational mechanisms (Rosenbaum, Carlson, & Gilmore, 2001; Schmidt & Bjork, 1992). However, someone who is likely to take big risks in black-jack may not be willing to do so in race-car driving, and vice versa. Relatedly, while optimal decisions are made in perceptual-motor tasks they are not made in mathematically equivalent financial betting tasks (Augustyn & Rosenbaum, 2006; Gepshtein, Seydell, & Trommershäuser, 2007; Trommershäuser, Landy, & Maloney, 2006; Tversky & Kahneman, 1974).

The latter outcome makes it unclear how risk-taking in intellectual tasks like choosing financial bets transfers to risk in more perceptual-motor tasks like driving or rock-climbing.

METHOD

Participants

Twenty-five right-handed undergraduate students were recruited from Penn State's Introduction to Psychology course. The students received credit for taking part in the study. The method was approved by the Penn State Institutional Review Board.

Procedure, Apparatus, and Design

As shown in Figure 1, in an experimental trial (in this case, the very first trial for one participant), the participant faced a computer screen on which appeared an empty circle in the middle of the screen (the <u>home</u> target) as well as two other circles: the <u>base</u> target (containing the number 8 in the example shown in Figure 1) and a <u>test</u> target (containing the number 20 in this example). When the participant clicked on the home target, it disappeared. The subject then clicked on the base target or on the test target at his or her discretion. If the participant clicked on either target within the time allowed to reach it target within the block of trials, s/he received the score shown in the target s/he chose to move to. The time allowed for capturing base or test targets was the same within a block of trials but decreased in successive blocks of trials. If a participant clicked on a base or test target too late, her/his score did not increase.

After the base target or test target was clicked, the two targets and their numbers disappeared. The screen turned blue if the subject clicked in the chosen target <u>within</u> the allotted time. Alternatively, the screen turned red if the subject clicked in the chosen target <u>beyond</u> the allotted time. The red or blue screen appeared for .25 s, after which the next array of circles appeared and remained on the screen until the participant clicked on the home target. Once a click was registered in the home target, the home target disappeared and the computer clock used to time the movement target was activated and was stopped only when a click was registered in the base target or test target.

The experiment was controlled with a program written in MATLAB and was run on a Dell PC using a standard mouse and 15" flat panel monitor. The display was automatically fit to the dimensions of the monitor by stretching the MATLAB window within a 7.5 by 7.5 normalized unit square centered on the middle of the screen.

Each of the targets -- the home, base, and test target -- were circular regions defined by a radius of 0.2 normalized units throughout the experiment. The base target was always 0.8 normalized units from the center of the home target. The test target varied from trial to trial, with its distance from the center of the home target varying quasi-randomly from 1.0 to 3.0 normalized units in steps of .4 normalized units. Each test target distance was presented 6 times without repetition per distance in a random order, resulting in 36 trials in each of 6 blocks. The base target could appear anywhere between 22.5 degrees and 337.5 degrees on the unit circle and the test target could also appear anywhere within this region subject only to the constraint that it was separated by at least 45 degrees from the base target.

The time allowed to acquire a base or test target started at 0.9 s for Block 1 and decreased to 0.4 s in steps of 0.1 s in successive blocks, regardless of the participant's performance. Scores for a given target were defined with Fitts' Law in mind (Fitts, 1954), using a velocity-based system. The score for a target was defined by taking the target's distance from the home target, dividing that distance by the target deadline for the block, and multiplying the ratio by 10.

The point value associated with each target was shown in the center of the base target and in the center of the test target. Additionally, as shown in Figure 1, participants were shown their cumulative score as well as the current trial number and block number relative to the total number of trials and blocks to be tested in the experiment.

Data Analysis

The data were analyzed with the aim of characterizing the risk-taking of individual participants. Because there were 36 opportunities for a participant to click on a test target rather than a base target in each block of trials, a participant could do so between 0 and 36 times per block. Similarly, a participant could capture a test target within the allotted time between 0 and 36 times per block. Calling the first number $\underline{a}$ and the second number $\underline{c}$, the risk, $\underline{R}$, for a block was defined as

$$\underline{R} = (\underline{a}-\underline{c})/\underline{b},$$

with $\underline{b} = 36$ being the number of trials per block. Dividing by $\underline{b}$ allowed for normalization, given that $0 \leq (\underline{a}-\underline{c}) \leq \underline{b}$. When $\underline{a}$ exceeded $\underline{c}$, the participant was risky, attempting the test target more often than s/he could capture it within the allotted time. Conversely, when $\underline{c}$ exceeded $\underline{a}$, the participant was conservative, attempting the test target less often than s/he could capture it within the allotted time. Finally, when $\underline{a}$ equaled $\underline{c}$, the participant was neutral, attempting the test target at the same rate s/he could capture it within the allotted time (probability matching).

RESULTS

The mean normalized riskiness scores over participants ranged from 0 to .43. The frequency histogram of the normalized mean riskiness scores, shown in Figure 2, is consistent with a normal distribution.

A second analysis focused on the relation between risk and block number. As shown in Figure 3, risk changed with block number, $F(5, 120) = 7.91$, $p < .01$. This outcome is not a trivial consequence of the design of the experiment such that risk-taking <u>had to</u> increase as the blocks went on. This potential concern was not applicable because we tallied values of <u>a</u> and <u>c</u> for the <u>test</u> target rather than for the <u>base</u> target. The test target always had a higher index of difficulty (Fitts, 1954) than the base target. Hence, there was no a priori reason why participants had to increase their riskiness by attempting more test targets as the blocks continued. A final remark about the relation between risk and block number is that we did not conduct a trend analysis for these data because we had no particular hypothesis about this.

A third analysis concerned the relation between mean risk and standard deviation of risk. As shown in Figure 4, these two variables were positively related; the correlation between them was .83. This outcome indicates that more risky participants showed more risk variability than did less risky participants. Apparently, participants who were more inclined to take risks were more likely to alter their risk-taking strategies than were participants who were less inclined to take risks.

DISCUSSION

The method presented here yielded individual differences in risk-taking. Most participants had risk values between .1 and .3. These values translate to a range of 3.6 to 10.8 more attempts than successful captures of test targets given the 36 trial blocks; see the equation above. On the other hand, some participants had considerably lower risk values and others had considerably higher risk values.

What was the relation between risk and optimal performance? We addressed this question in a fourth analysis. Behind the analysis were two ideas. The first was that there would be a linear relation between subjects' final scores and their mean mouse velocities given the way scores were awarded. This expectation was confirmed, as shown in Figure 5. The second idea was that deviations of participants' points from the linear relation between final scores and mean mouse velocities would reflect the contribution of individuals' decision-making, apart from their movement speed. According to this second idea, a participant with a point <u>above</u> the trendline in Figure 5 would be one who made decisions that enabled him or her to do better than would be expected from his or her mean speed alone. Conversely, a participant with a point <u>below</u> the trendline in Figure 5 would be one who made decisions that caused him or her to do worse than would be expected from his or her mean speed alone.

Given these assumptions, we asked whether the risk levels observed by our participants (Figure 2) afforded the greatest decision-based benefit to performance. Figure 6 shows that it did. In Figure 6, we plot, on the ordinate, the individual participants' differences from the best-fitting straight line within Figure 5 against, on the abscissa, the participants' risk scores. Calling the values on the ordinate "Decision-Based Contribution to Performance," the best (most positive) decision-based contributions to performance were associated with typical levels of risk. As expected if the typical levels of risk afforded the best decision-based benefit to performance, the data points in Figure 6 were reasonably well fit with a quadratic function, $F(1,21) = 4.325$, $p < .05$. A quadratic function provided a better fit than did a linear function, $F(1,22) = 6.22$, $p < 0.05$

These results are consistent with recent studies indicating that, for the most part, participants perform optimally in manual aiming tasks (Augustyn & Rosenbaum, 2006; Gepshtein, Seydell, & Trommershäuser, 2007; Trommershäuser, Landy, & Maloney, 2006). Our results extend this finding to a task where participants chose between two possible targets. In the studies of Trommershäuser and her colleagues, just one target was presented in each trial, along with penalty zones, not to be hit; the dependent variable was where the target zone was hit. In the study of Augustyn and Rosenbaum

(2006), there were two possible targets but the one target that was called for in a trial was specified by the computer, not the participant; the dependent variable was where along the straight line joining the two targets participants placed the cursor to get the best jump on the one target that might be called for.[1]

In keeping with our expectation that we would find some individual differences in risk-taking, we did find such differences, as shown in Figure 2. Furthermore, as shown in Figure 6, we found that participants with extreme risk values also had negative decision-based performance contributions. These results show that not all individuals will take risks that maximize decision-based contributions to performance. Some individuals will be overly risk-averse while others will be overly risk-inclined.

Why some individuals use risk in ways that are sub-optimal is, of course, an open question that can be addressed in future research. For now, we can say that the capacity of our method to uncover such individual differences points to the promise of our method for identifying people whose risk-taking may get them into trouble. If accidents can be prevented by identifying such

[1] In the study of Augustyn and Rosenbaum (2006), the allowed movement time decreased as the experiment progressed, as in the present study. By contrast, in the studies of Trommerhauser and her colleagues, the allowed movement time was fixed. These similarities and differences in methods suggest that changing the allowed movement time in the present study was not the cause of suboptimality in some participants. People can make aiming movements at different speeds without qualitatively changing the relation between movement time and Fitts' (1954) index of difficulty (Young, Pratt, & Chau, 2009).

individuals in advance, that would be a happy outcome of this and related studies.

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AUTHOR NOTES

This study was completed as an independent study project by the first author when he was an undergraduate at Penn State University. Sangdi Chen, Gary DeNardo, and Austen Talbot were fellow undergraduates who helped with data collection. Their help is gratefully acknowledged. Correspondence should be directed to the first author (jck221@psu.edu) or second author (dar12@psu.edu).

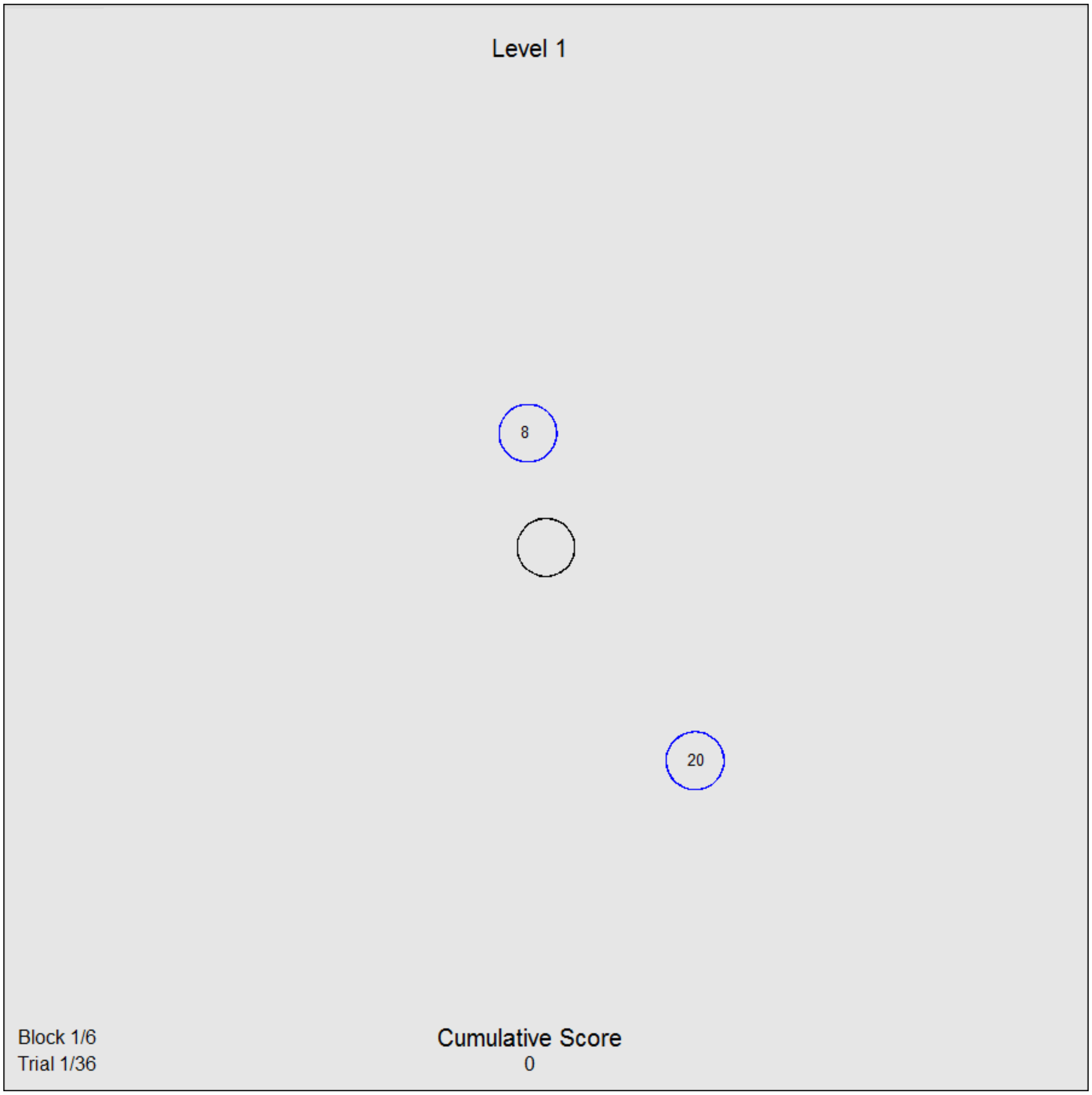

Figure 1. Screen shown in the first trial of the first block of one participant's experience in the psychomotor risk experiment.

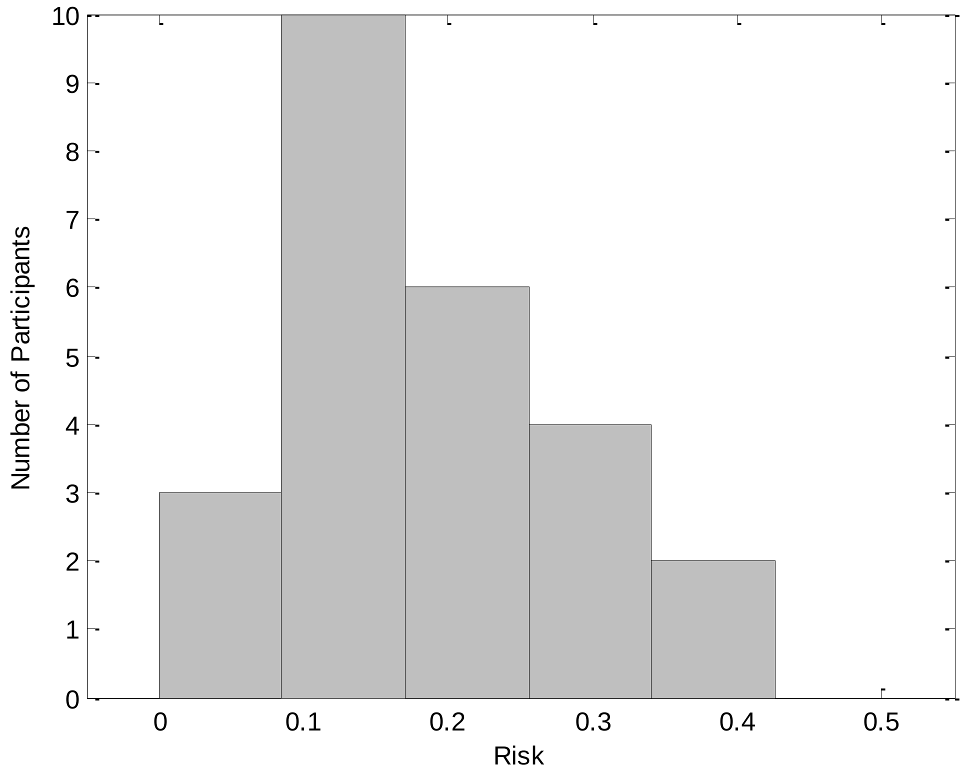

Figure 2. Distribution of mean risk values over participants.

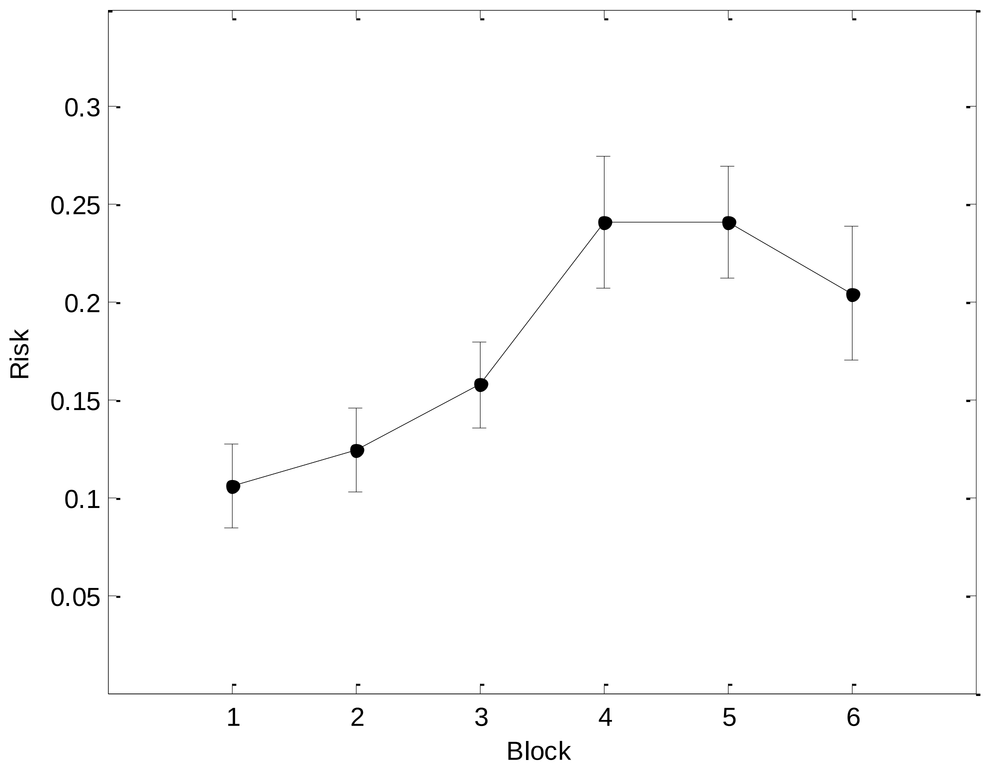

Figure 3. Mean risk (±1 SE) as a function of block number.

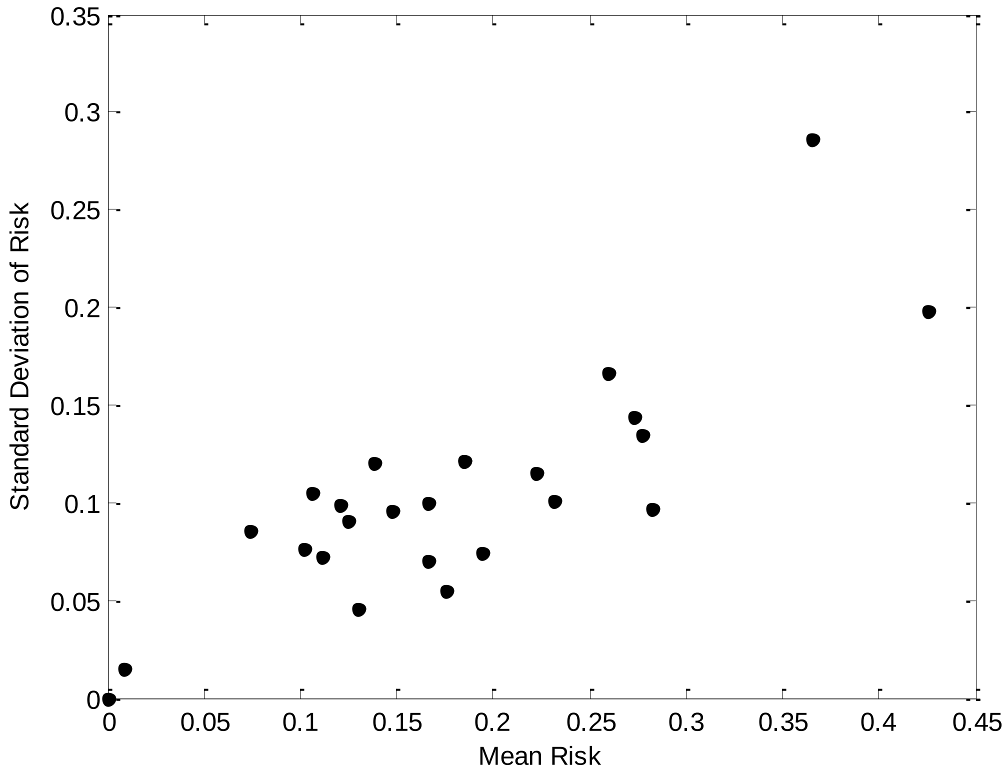

Figure 4. Relation between standard deviation of risk and mean of risk.

Each point is for one participant.

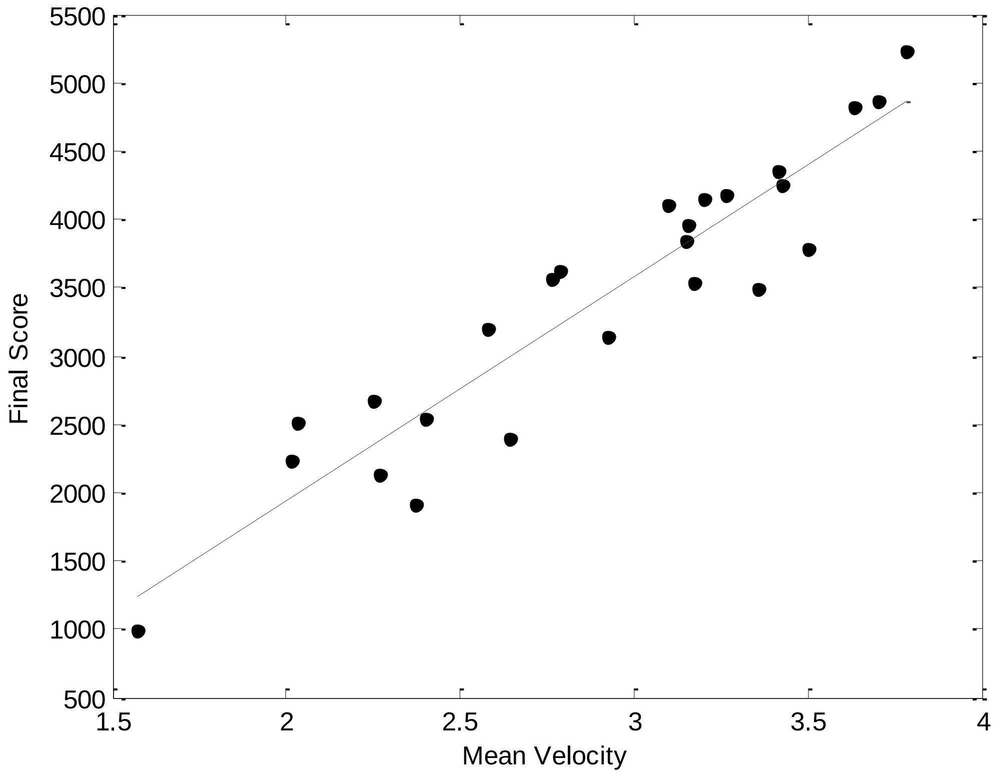

Figure 5. Final score as a function of subjects' mean velocities (distance from home target to chosen target divided by movement time). Each point is for one participant.

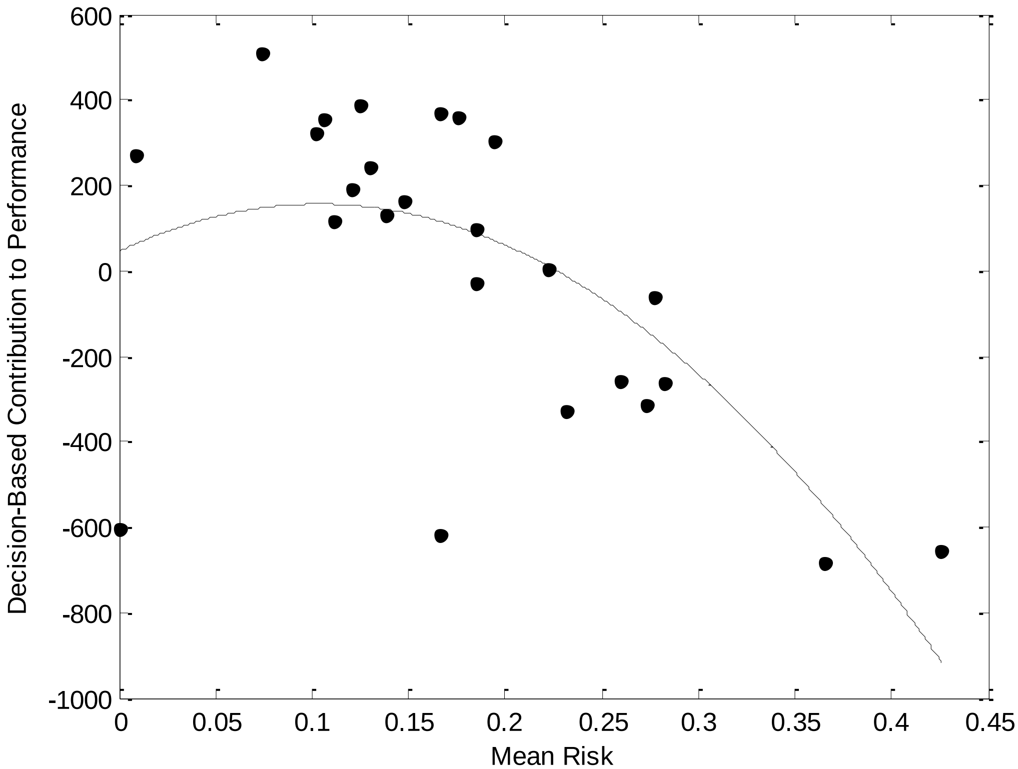

Figure 6. Relation between decision-based contribution to performance and mean risk. Each point represents one participant.